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THE OZONIZATION OF WATER.

BY GEORGE A. SOPER, PH.D., ENGINEER AND CHEMIST, NEW YORK CITY.

[*Read February 14, 1900.*]

Among the interesting new processes for the purification of water and sewage which have appeared in the last ten years, the latest to attract public attention is the ozone treatment. As is not unusual with new inventions, large claims have been made for the ozone process, some of which will probably never be realized; but in view of the increasing interest which water-works people are showing in the subject, and the possibilities which are apparent in it, it may not be unprofitable for us to review briefly the principal facts upon which current arguments in favor of ozonization are based.

At the outset it should be stated that the theory of ozonization is extremely simple. It consists in bringing about a thorough mixture of the water to be purified and a quantity of atmospheric air which has been ozonized. When the ozone, which is a very active condition of oxygen, is brought into contact with the water, some of the organic impurities of the latter are oxidized. Oxidation, it will be remembered, is, in chemical parlance, combustion, and the effect of the ozone treatment is to destroy or burn up the objectionable matters.

It is customary to convert the oxygen of the air into ozone by means of electricity and to apply it by what might be considered a very thorough system of aëration.

The idea of purifying water by ozone appears to have had its beginning with Frölich, an engineer of the firm of Siemens & Halske, of Berlin. He was engaged in experimenting with ozo-

nizers in the hope of producing an apparatus which would yield a larger quantity of ozone for a given volume of the oxygen supplied to it than had been found possible up to that time.

Frölich's efforts to increase the efficiency of his ozonizers do not seem to have been particularly successful, but in papers published by him in 1891, upon the subject of his experiments, he makes some interesting suggestions of a new use to which the mixture of ozone and air obtained from his apparatus may be put.

He states that when impure water is treated with ozone, its quality is greatly improved. The dissolved ammonia is partly converted into nitrates, iron, when present, is precipitated in the form of hydrate, and the water is sterilized.

Frölich was not a biologist or chemist, and beyond pronouncing his opinion of the germicidal action of ozone and its power to mineralize organic impurities in water, he made no attempt to establish the usefulness of the process he proposed.

The publication of Frölich's papers was, however, soon followed by an investigation into the power of ozone to sterilize water, which was authoritative. The research was undertaken for the Imperial Board of Health of Germany, by Ohlmüller, at Berlin. Various waters were used, and the action of ozone toward many species of bacteria was carefully studied. Ohlmüller, working with a small experimental plant, found that sterilization was easily effected in distilled water to which bacteria were added. In two minutes he killed 12 247 000 typhoid bacilli and 2 791 000 cholera germs. Sewage was difficult to treat successfully, and it was not considered feasible to sterilize water which contained much organic matter in suspension.

The first attempt to work out the practical conditions under which ozone could be applied to the sterilization of large volumes of water was made by Baron Henry Tindal, of Amsterdam, who built a sterilizing plant with a capacity of 7 500 gallons per day, at Oudshoorn, near Leyden, Holland, in 1895.

The water treated was taken from the Old Rhine. It was polluted with the wastes of factories and towns and the drainage of farm lands. It was highly colored and had an unpleasant odor. There was no difficulty, however, in sterilizing the water after filtration. Very careful studies were made of the species of bacteria found in the raw water, and in some of the tests particular species were sown in order to observe the effect of ozone upon them. It was found

that the most resistant bacteria could be destroyed under conditions which promised industrial success.

The appearance of the Old Rhine water was much improved by ozonization, the color and odor being reduced, and the chemical qualities as indicated by the permanganate figure were improved fifty per cent. Finally, the water after treatment by ozone contained no substances prejudicial to health. It was free from taste and was pronounced to be in all respects excellent for drinking purposes.

Our information concerning the results of the test at Oudshoorn is taken from an official report made by Dr. Van Ermengem of the University of Ghent, who investigated the plant as an expert for the Belgian Government.

At first the ozone was generated by a Siemens apparatus similar to that which had been employed by Frölich and Ohlmüller. It consisted of two large concentric glass tubes so arranged as to leave an annular space between them through which a stream of air could be made to pass. The inner tube was filled with acidulated water and the apparatus was immersed in a bath of the same liquid. On connecting the water in the inner tube with one pole of a powerful induction coil and the water outside of the larger tube with the other pole of the coil, a current of electricity was established through the air in the annular space.

The nature of the current produced in an air-gap under such circumstances is known as the silent or brush discharge. Under properly regulated conditions there is no sparking, but a violet-colored flame which has the peculiar power of converting oxygen into ozone when the former is brought into contact with it.

In Ohlmüller's hands the Siemens apparatus yielded ½ cubic foot per minute of ozonized air, which contained approximately four per cent. of its weight of ozone. It was supposed that increased voltages would produce increased yields of ozone, but it was found at Oudshoorn that electric potentials above 4 000 volts endangered the glass walls of the Siemens apparatus. To avoid this difficulty, celluloid was substituted for glass, and finally the use of dielectrics was discarded altogether for a new form of ozonizer which was invented by Schneller, an electrician connected with the test. This point is particularly noticed here for the reason that an important step was taken in the development of ozonizers when the old forms requiring the use of delicate dielectrics were abandoned. The new apparatus,

if not more efficient, was more durable in character and better suited to the uses of water works than the old types.

The new ozonizers used currents which were transformed to 50 000 volts. The air which was to be ozonized was filtered, dried and chilled. The improved apparatus for converting the oxygen will be described presently. Sterilization was effected by applying the ozone to the water by bubbling and by spraying. It was found that spraying gave a more intimate contact, but that the contact by bubbling could be continued longer.

At the Hygienic Exhibition held at Paris in 1896, an experimental ozone installation was made by Baron Tindal to treat the water of the Seine. The leading features of the plant resembled those at Oudshoorn, the same type of apparatus being employed. Electric power was taken from the general electric light circuit of the exhibition to operate a small dynamo whose current was transformed for use to 50 000 volts.

The ozonizers were of the sort that had been invented at Oudshoorn. They consisted of five glass-lined rectangular boxes 10 x 14 x 23 inches. Suspended from the cover of each were packages of platinum foil sheets whose edges were separated from the walls of the boxes by a space of about $\frac{3}{16}$ inch. On the glass walls opposite the platinum sheets were fastened thin gold plates. The gold was grounded and the platinum was connected with the electric transformers through glycerine resistance cells placed above the boxes. Air passed through the boxes and became ozonized by contact with the electric flames which played between the platinum and gold.

The sterilizing apparatus consisted of upright columns through which the water and ozone were pumped, passing from the bottom upward. The water and air escaped at the top. Most of the ozone was absorbed. The plant had a designed capacity of about 30 000 gallons per 24 hours when treating filtered water from the Seine which contained two parts of organic matter per 100 000.

Drs. J. Repin and Marmier of the Pasteur Institute, both of whom examined the sterilizing capacity of the plant, pronounced the Oudshoorn results fully sustained, but the bacteriological data which these gentlemen collected have never been published. The chemical effects were, as reported by Repin, — chlorine not changed, nitrates reduced slightly, partial precipitation of the carbonates of lime and magnesia and sulphate of lime. Color, odor, and taste were improved.

Regarding the cost of ozonization, it was considered that where water does not contain more organic matter than is represented by 0.4 part permanganate per 100 000, about 1 500 gallons of water can be purified with an expenditure of energy equivalent to 1 H. P.

At the Brussels Exhibition of 1897, a third trial plant for the ozonization of water was erected by Baron Tindal, with a capacity of about 100 000 gallons a day. With this plant, water from the infiltration galleries of Brussels was readily sterilized, as were samples taken from polluted canals near the coast; the latter, however, being first filtered to remove suspended solids. The essential features of the plant were similar to those at Oudshoorn and Paris. A report to the Government was made upon the efficiency of the Brussels plant by Dr. Marmier, who, it will be remembered, was mentioned in connection with the Oudshoorn test, and Prof. Leon Gerard of the University of Brussels.

Not the least important of the effects developed at Brussels are the data which relate to the cost of producing the ozone and the quantity which was required to sterilize the water. As the result of careful experiments it was announced that the concentration of ozone from the ozonizers was 4.5 mgs. per liter of air, which is about one third of one per cent. by weight. It was found that about three grams of ozone could be made with 1 H. P., that this amount of ozone would purify about 22 000 gallons of water when the organic matter did not exceed 10 parts per 100 000, and that the cost per 1 000 000 gallons was about nine dollars.

There are at present two municipal ozonization plants in Europe, both of which I have seen in operation. The first was built in 1898 at Blankenberg on the Belgian coast, to sterilize 500 000 gallons per day of canal water. As in the experimental trials already referred to, the water is filtered before treatment with ozone.

There are no special features of interest in the electrical apparatus for producing ozone at Blankenberg, except that for the glass boxes with metallic electrodes there are substituted covered troughs of metal in which there are suspended a number of platinum combs. The electric discharge takes place between the points of the combs and the adjacent walls of the troughs.

The sterilizers are three in number. They are situated in a pump house adjoining the filters, and occupy a small space near the electric machinery.

The sterilizers resemble small standpipes in appearance, and are

made of glaze-lined flanged iron pipe, each length of which is about three feet in diameter and three feet high. Ten such lengths are used in each column. The water and ozone enter the sterilizers at the bottom and pass upward. To insure a thorough mixture, there is placed at each joint a screen or false bottom, which consists of a plate of celluloid with holes $\frac{1}{30}$ inch in diameter. There are 126 such holes to the square inch. To avoid undue pressure upon the screens and a reduction in the flow which would result from the small area of the holes, by-passes are arranged to carry a part of the water around the joints. Peep-holes of glass are set in the sides of the sterilizers, through which a view can be had of the mixture of ozonized air and water. The distribution of small bubbles thus observed is very complete. The frictional resistance offered by the sterilizers to the passage of the water is said to be less than four feet. The electric power required to ozonize the air was given to me as 4 H. P. per 1 000 000 gallons of water.

The largest system of ozonization thus far installed is at Paris. There a plant with a designed capacity of 3 170 000 gallons of sterilized water per day has been in operation more than a year.

The plant is situated at Saint Maur-les-Fossés, where a water-works station with pumps and English filter beds had previously been established to purify the water of the Marne for the city of Paris. The ozone generators and sterilizers are substantially like those at Blankenberg. There are three sterilizing columns, composed of twelve sections each. The water escapes at the tops of the columns and flows out by gravity into a small open tank at a level of perhaps eight feet above the level of the filter beds. The water after ozonization is bright and clear and without odor or taste.

The bacterial character of the Marne after filtration and ozonization was reported upon for the information of the Dutch Government by Dr. Ferdinand Begançon, Chief of the Bacteriological Laboratory of the University of Paris, under date of January 12, 1899. Of twelve samples of water treated with ozone which he collected, all were sterile after two weeks at 20° C., in gelatine. Of ten samples sown in broth and kept for two weeks at 37° C., two developed the *bacillus subtilis*; the rest were sterile. Another analysis made by Dr. Begançon a month earlier gave identical results.

The cost of sterilizing the Marne water at Paris after filtration has been given to me as $5.90 per 1 000 000 gallons, which includes operating expenses, interest charges, and salaries, as follows: —

ITEMIZED COST OF STERILIZING FILTERED MARNE WATER AT PARIS.

Energy required for ozonizer	3.0 H. P.
,, ,, ,, air pump	1.5 ,,
,, ,, ,, water pump	12.0 ,,
Total energy	16.5 H. P.
Cost per day, at 2 cts. per H. P. per hour	$7.90

Other daily expenses are : —

Salaries of three men @ $200 per month	$6.66
Interest charge of 3½% upon $20 000 (cost of plant)	1.94
Interest charge of 4% upon $20 000 (to cover depreciation)	2.22
Total salaries, etc.	10.82
Cost of energy, as above	7.90
Total cost of ozonization per day	$18.72

Capacity of plant, 3 170 000 gallons per 24 hours.

In concluding this very brief review of some of the main facts which have been brought out in connection with the ozonization of water, it may be of interest to quote a few words from a report which was made to the city of Lille regarding the feasibility of employing a system such as has been described to sterilize its water supply.

It will be remembered that Lille is a city of about the size of Detroit, with say 200 000 inhabitants. The report is dated February 12, 1899, and signed by a commission of five experts, among whom was Dr. Roux, one of the directors of the Pasteur Institute of Paris. The findings of the commission were based upon tests with an experimental plant which extended from December 10, 1898, to February 12, 1899. Among the conclusions are the following, taken from a free translation of a copy of the original document : —

1. "The method of sterilizing drinking water based upon the ozonizers and sterilizing column . . . has an efficiency which is undeniable and superior to that of any other process of sterilization known which is susceptible of application to large quantities of water.

2. "The simple arrangement of the apparatus, its strength, the uniformity of its output, and the regularity of its action give every assurance that it is in fact an industrial apparatus.

3. "All the pathogenic and saprophytic microbes that were contained in the water studied by us have been entirely destroyed by the passage of the water through the ozonating column. Only some of the germs of the *bacillus subtilis* were able to resist it successfully.

"We have counted about one germ of this species in 15 c.c. of water after treatment with a mixture of $\frac{1}{2}$ of 1 per cent. of ozone in air. With a concentration of $\frac{3}{4}$ of 1 per cent. the number of germs of *bacillus subtilis* capable of reviving in a bouillon culture medium is reduced to less than 1 in 25 c.c. of the water treated.

"It is necessary to observe that the *bacillus subtilis* (microbe of hay) is entirely inoffensive to man and animals, and that the germs of this microbe resist for the most part methods of destruction; that of the heat of steam, for example, under pressure at 110° C. It is not necessary to destroy them completely in drinking water, and we consider as very sufficient the sterilization obtained by air ozonized with a concentration of $\frac{1}{2}$ of 1 per cent. under the conditions arranged. . . .

4. "The ozonization of water does not introduce any foreign element prejudicial to the health of those required to use it."

Very recently there have appeared in foreign journals some accounts of an experimental research conducted by Dr. Th. Weyl, into the sterilizing value of ozone and of ozone in connection with metallic iron. In the experiments with iron and ozone, the water was treated in such a way as to form a precipitate of ferric hydrate. It was found that water treated in this way was more efficiently purified than by simple ozonization or by treatment with iron and subsequent aëration. With iron and ozone, 87 per cent. of the bacteria were destroyed or removed; with iron and air, 61 per cent. disappeared, and with ozone alone there was a reduction of 5.9 per cent. The original number of bacteria was 45 360 per c.c.

It is to be regretted that Dr. Weyl has not stated what part of his results are due to ozonization and what to coagulation — two very different phenomena. Until this has been determined it would seem preferable to leave the question of the ozone-iron treatment for discussion under another heading, for it is evident that the iron precipitate must be eventually subsided or filtered off, and that provision must be made similar to that necessary for the disposal of the flocculi which result from the treatment of water by alum, before the water can be considered purified. Dr. Weyl is very sanguine of the future of ozonization, as indeed are many of the investigators who have examined the sterilizing action of ozone in water.

Some experiments which I have made with ozone have had as much reference to a reduction in color and odor in water as to its sterilization, for it seemed that the very thorough investigations of

Ohlmüller, Van Ermengem, Marmier, and Roux proved beyond doubt the germicidal capabilities of the process.

The plant with which my tests were carried on was located at Columbia University, and consisted of electric apparatus for the generation of ozone and various cylinders and other vessels in which the ozone-water contact was brought about.

I found that waters in which colors and odors were artificially produced were very greatly improved by the ozone treatment. Colors as dark as 6.0 of the platinum-cobalt scale, produced by soaking dried leaves in distilled water, were reduced to 1.0. Browns, reds, and greens were bleached without difficulty. Even the color of strong solutions of alkaline and acid litmus, indigo and alizarine, were easily destroyed.

The odor experiments were conducted with samples of distilled water in which various odors, such, for example, as that of herring, cinnamon, onion, geranium, and putrid beef, were induced. Ozonization removed the strongest natural odors that could be found.

When experiments were made with naturally colored waters very similar results were observed. With Croton water it was possible to reduce the bacteria 74.8 per cent., the permanganate figure 12.5 per cent., the color 35.1 per cent., and the odor entirely, by passing ozonized air containing 0.3 per cent. of ozone for fourteen minutes through it.

It will be observed that there are two steps to the process of ozonization, — the production of the ozone and its application to the water.

Theoretically, a complete plant consists of filters, dryers, and coolers to prepare the air for treatment; an alternating current dynamo, transformer, and ozonizer to convert the oxygen; a pump to keep the air in circulation, and a sterilizer in which to apply the ozonized air to the water. Conditions which favor the production of ozone are great dryness and very low temperature of the air, and its continued exposure to the electric flame. Sparking in the electric apparatus occasions loss of ozone by converting it back to the more stable form of atmospheric oxygen. Theoretically, it should be better to exhaust the air from the ozonizers than to force it through under pressure, and this is the method now generally employed. Owing to the corrosive action of ozone, it is forwarded to the sterilizers in glaze-lined pipes, although when the gas is perfectly dry such a precaution should not be necessary. In the absence of moisture, metals and organic matters

are not very readily attacked. Owing to its instability, ozone cannot be compressed or stored to advantage.

Two methods of applying the ozonized air to the water have been patented in the United States by Schneller and Van der Sleen, two men who were very actively concerned in the conduct of the Oudshoorn experiments. It may be said, however, in regard to these patents, that they specify definite forms of apparatus with which the inventors consider the system should be carried on.

Of prime importance in applying ozone to water is the necessity for bringing about a very thorough contact. Owing to its purely chemical character, ozone is very certain to attack the most easily oxidizable matters first. Its action upon bacteria is therefore modified by the presence of less resistant substances. Impurities which are most uniformly distributed, such as coloring matters, for example, will not fail to be affected by even small amounts of ozone, but bacteria which are associated with masses of solid matter in water will be difficult to destroy.

The cost of purifying 3 000 000 gallons of water per day by the use of ozone has been given as $6 per million gallons, reckoned on the basis of a plant of upwards of 3 000 000 gallons capacity. Smaller plants have usually indicated a higher price than that stated, but it would appear safe to consider the lower figure to be more exact from the fact that it has been obtained under more strictly practical conditions. If we consider that it is necessary to filter water thoroughly before applying the ozone, and that the cost of filtering will be approximately $10 per million gallons, we will have $16 per million gallons as the total cost of treatment. It will be remembered that sterilization by heat was advocated a few years ago by a prominent engineer of the middle West who considered it would cost $250 per million gallons.

It is very possible, under the conditions which exist at some of our American water works, that ozonization could be applied at a much lower cost than the data which have come to us from Europe would indicate. It would appear that other forms of sterilizers could be built, and that the loss of head which appears to be a considerable factor of expense in the operation of the Blankenberg and Paris plants could be reduced.

It is a question, however, whether there is an important field for the ozone treatment if it must be applied to waters previously filtered as carefully as has been the case in Europe. We are in the habit of

considering that waters which are filtered by English sand beds or mechanical filters are adequately purified, and it is doubtful whether an expense approximately equal to half the cost of filtration would be justified in a supplementary treatment of such waters.

But the ozone treatment presents other claims for consideration than those which rest merely upon sterilization. As a purely chemical agent capable of producing rapid oxidation it appears to me that there lies open for it a promising field in water purification. Used in connection with iron it is possible for ozone to be of assistance in forming a flocculent precipitate for the coagulation of turbid waters. With ground waters containing iron, it should be of special service where simple aëration is not sufficient to precipitate. In the removal of color caused by the presence of organic impurities, and of odor due to microscopic organisms, ozonization could, in my opinion, be frequently applied to great advantage. In such directions, however, there is much need of careful experimental study in order to determine the conditions upon which ozonization can be most effectively and economically applied.

Discussion.

Prof. Leonard P. Kinnicutt.* I think we are all very greatly indebted to Dr. Soper for the interesting account he has given us of the ozonization of water. Many of the facts he has given are entirely new to me, and are the results of his own careful investigations. I agree with him that the greatest opportunity for the use of ozone with water is in the removal of color and odor, and the point which he touched on last, the formation of flocculent precipitates without the addition to the water of anything that can in any way be injurious, is certainly very suggestive. Can we by means of iron and ozone, or by some other substance in the place of iron, produce in water a flocculent precipitate which will carry down with it, as alum does, the organic impurities and the bacteria contained in the water? This is a question which offers an opportunity for a large amount of original research.

Dr. Soper has shown us very clearly how water can be sterilized by the use of ozone, but I did not make out from his paper how much of the organic matter contained in a water could be thus removed,

* Professor of Chemistry, Worcester Polytechnic Institute.

and I should like to ask if he can give us an idea, judging from the albuminoid ammonia or the oxygen consumed, of the amount of purification that has been obtained by the ozone treatment.

The cost of treating water by the ozone method Dr. Soper stated as being about $16 per million gallons. This of course makes the process a very expensive one, and it seems to me that before it can become a practical process the cost must be reduced. This can be accomplished if we can reduce the price of obtaining ozone, and the question presents itself, Is there not a hope that in the future a cheaper method than that of passing silent electrical discharges through air, by which only about one fourth of one per cent. by volume of ozone is obtained, be discovered?

Only this last year a new method of obtaining ozone has been published, — the addition of fluorine to water. Fluorine itself is a gas, which was first isolated by the French chemist Moissan in 1886, and he has now shown us in connection with the properties of this gas that if it is added to water, oxygen is obtained which contains about fifteen per cent. of ozone. This method for obtaining ozone is not at the present time a practical one, but it shows that it may be possible in the next ten or fifteen years to find a method for producing ozone at a very much less cost than that at which it can now be obtained by the silent discharges of electricity through dry air. If this were achieved it would make the ozonization of water a practical process, and one which in many ways could be used to great advantage in the purification of water.

Dr. F. S. Hollis.* Dr. Soper's paper has been full of interest to me, and I think I have learned many things from it concerning the application of ozone to the purification of water. In regard to the disappearance of the odors which were added to the water, I don't know as I understand quite how long that took, or how much ozonized air was allowed to bubble through the liquid in order to drive off the added odors. That is a question I would like to ask.

Dr. Soper. In reply to Dr. Hollis I will say that the amount of ozonized air required to drive off odors is rather considerable. The probability is that the ozone is not wholly responsible for the beneficial effects, and that aëration alone would remove a part of the odors. The activity of the ozone is responsible to a very considerable extent in the case of odors which are known to be refractory to aëration. I think I have some data as to the amount of air required for some unit

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* Biologist, Metropolitan Water Works.

of water, and I will be pleased to give the information if I can find it among my papers before the discussion is finished.

Mr. H. W. Clark.* There are one or two things I would like to ask Dr. Soper about his very interesting paper. A very long article is published this week in *Engineering News*, which undoubtedly Dr. Soper has read, — a translation from a German paper, in regard to the meeting at which Dr. Theodore Weyl read his paper upon the ozonization of water, together with a discussion of the paper by several engineers in charge of sand filtration plants. In his paper Dr. Weyl made a statement that plants upon a practical scale were in operation in Belgium, Holland, and Paris. After this paper was read, and during the discussion, Mr. Halbertsma, a Dutch engineer, stated that there was no plant in operation in Holland on a practical scale, and that Tindal's plant in Paris was simply a small laboratory plant. Now, I do not know just when that discussion occurred, but either there was a remarkable ignorance displayed at that meeting in regard to the operation of the large ozonization plants at Paris and at Blankenberg, or else they had later information than Dr. Soper has. I presume Dr. Soper's information is later than theirs, however.

Then another thing, Dr. Soper, in regard to your experiments at Columbia University, I think you said that with waters which you had colored artificially you were able to eliminate 75 or 80 per cent. of the color, and even more in some cases; but when you applied the process to a natural water, that is, I presume, to the Croton water, you only eliminated 35 per cent. of the color. That, of course, is an amount which ordinary sand filters will take out, running at their usual rate. And then, in regard to the plant at Paris, I do not think you gave figures showing the percentage of removal of bacteria by the preliminary filters, and how many bacteria the ozone really had to kill to sterilize the filtered water, what percentage it was of the number in the raw water as it went to the filters. Those are two or three points I should like to have a little more information about.

Dr. Soper. Replying to Mr. Clark's questions, I think I might point out that the discussion before the society of German waterworks people was rather unfortunately produced, and that the subject of ozonization was not considered fairly upon its merits. Dr. Weyl is an enthusiast, and although he is a chemist and hygienist of some repute in Europe, he was not especially tactful nor discreet in the way

* Chemist, Massachusetts State Board of Health.

he brought about the discussion. He claimed at the outset that the efficiency of natural filters had been overrated, and that because of misplaced public confidence in them they had been the means of producing severe epidemics of disease in Europe, and that they were really a very dangerous institution instead of a means of protection. And that claim, rather stoutly presented, at once aroused the indignation of the German water-works superintendents and engineers, who had done a great deal to develop sand filtration, and, I may say, who knew very well that their sand filters were largely efficient, and had not been misrepresented as to their ability to protect the consumers against outbreaks of epidemic. I do not remember that Mr. Halbertsma said that there were no ozone plants in operation in Belgium.

Mr. Clark. No, he did not.

Dr. Soper. He did say that there were none in Holland where Baron Tindal came from, and he pointed that out in a sarcastic way as being significant of the inconsequence of the ozone system. As to the experimental nature of the Paris plant, I have only the figures which I have given, and I have no doubt many of them are not at all new to Mr. Clark, or to very many of the other gentlemen present. The plant is considerably larger than that at Blankenberg, and the amount of water treated at Paris has been stated in French periodicals.

As to the experiments at Columbia University with color, I did say that very dark colors could be removed almost entirely by the ozone system and that I had removed them. I did not say that that could be done upon an economical basis. Such colors as I experimented with would no doubt be darker than those ordinarily met with in water-works practice. I stated that a certain amount of color could be removed; if I remember rightly it was 35 per cent. or so, and other improvements made in the water under conditions that were practical, and that the treatment could be applied, as I applied it, to a water like the Croton water, which was filtered. If I have neglected any point, Mr. Clark, will you kindly suggest it again?

Mr. Clark. I would like to say in regard to the Paris plant that I have understood it was of the size you have described. I simply wanted to know whether it was not in use at the present time, or had not been in use for the past few months, and it was for that reason that Mr. Halbertsma made that remark, and whether you had any later information than what has been published within six months or a

year in the French journals. One other question I asked in regard to the Paris plant was as to the percentage of bacteria removed by the filters, and how many the ozone had to kill to sterilize the water.

DR. SOPER. I might state that I think that Mr. Halbertsma's reference to the Paris plant was to an experimental plant that was set up at the Hygienic Exposition, and that the operation of the present plant, which I have referred to, has been, perhaps, a little more recent than Mr. Halbertsma's information. There have been no experiments made with either the Blankenberg plant or the Paris plant, so far as I know; at all events, the results of such tests have not been published. The source from which I obtained the information regarding the quality of the effluent from the sterilizers gave no facts concerning the number of bacteria in the water applied to the sterilizers. The water was considered to be filtered as well as English sand beds ordinarily filter water in France, which is not as well as in other countries, undoubtedly, and it is presumable that there were considerable numbers of bacteria in the water. The principal point seemed to be that the water was practically sterile after treatment.

MR. HORATIO N. PARKER.* Mr. President, I should like to refer to an objection which was raised in that discussion before the German engineers, not, perhaps, a practical one, but one to which Dr. Soper may have a ready answer. The point was raised whether it would be safe to take a highly polluted water, — I mean by that one containing an enormous number of bacteria, — and treat it by ozone, and then deliver it directly to the people; whether there would be any ill effects liable to follow from the use of the water.

Then I should like also to know if Dr. Soper has at hand any figures as to how bacteria would behave when introduced into this water sterilized by the ozone process; that is, supposing you were to introduce a culture of typhoid into the sterilized ozone water, what would take place?

And then, furthermore, without wishing to be discourteous at all to Dr. Soper, I should like to ask him whether he has any figures in regard to the color of the water that has been treated by ozone after it has come from the filters; that is, was there a large percentage of the removal of the color subsequently to the sand filtration? I should think possibly somewhere in the work such figures might have been obtained, but unless my memory fails me we have n't been given any such this afternoon. Of course, Mr. Clark has already asked

* Assistant Biologist, Metropolitan Water Works.

that question, and I don't want to embarrass Dr. Soper any by repeating it.

Dr. Soper. Taking the last question first, I am very glad of the opportunity to say that I have here the results of an analysis of the

CROTON WATER BEFORE AND AFTER TREATMENT BY OZONE.

March 16, 1899.

Results in Parts per Million.	Before.	After.
Turbidity	none	none
Color	2.5	1.0
Odor — Cold	none	none
Odor — Hot	none	none
Chlorine	4.0	4.0
Residue on Evaporation	54.	54.
Loss on Ignition	33.	30.
Nitrogen as — Albuminoid Ammonia	.170	.090
Nitrogen as — Free Ammonia	.060	.056
Nitrogen as — Nitrites	trace	none
Nitrogen as — Nitrates	.75	.80
Bacteria per c.c. after 48 hours in neutral gelatine	416	44

EFFECT OF OZONE UPON ORGANIC MATTER AND BACTERIA IN CROTON WATER.

Date of Collection, 1899.	Period of Ozone-Water Contact.	Permanganate.			Bacteria per c.c.			Color.		
		Before	After.	% Dif.	Before.	After.	% Dif.	Before.	After.	% Dif.
March 14	10 min.	1.8	1.7	5.5	560	320	42.8	1.50	1.00	30.0
March 21	15 ,,	1.9	1.6	15.7	721	91	87.5	2.00	1.00	50.0
March 28	20 ,,	1.9	1.5	20.5	3 938	512	86.9	2.00	1.00	50.0
March 29	10 ,,	1.9	1.65	18.1	483	216	56.3	2.50	1.00	60.0
April 7	10 ,,	1.7	1.6	8.5	13 018	2 373	81.9	2.00	1.75	12.5

Croton water, made in March, 1899, in which the color was reduced from 2½ to 1 after filtration. In regard to the albuminoid ammonia point, which was raised by Professor Kinnicutt, the albuminoid ammonia was reduced from .170 to .09. The results of several analyses are given in the accompanying tables. As to the ill effects of drinking

water which had been treated with ozone, I would refer to the report signed by Dr. Roux, among others, in the case of the recommendations to the city of Lille, in which he says that there are absolutely no ill effects produced. To amplify that point somewhat, I might say that pure water is not considered a solvent for ozone. Ozone probably does not remain in solution in distilled water at all; perhaps very slightly in solution in waters that contain some organic or mineral constituents. But the effect, so far as it has been observed, after the water has stood for a few moments subsequent to the ozone treatment, is a slight increase in the dissolved oxygen. The ozone, if it were in solution and there were any organic matters, would soon be absorbed by the organic matters in process of oxidation.

In regard to the planting of typhoid germs in water which has been treated by ozone, I might say that, although there are no experimental or analytical data upon that point to my knowledge, there is every reason to believe that they would thrive there as well as in water not treated. The ozone process merely aims to sterilize water as heat might sterilize it, so far as the question of bacteria is concerned, so that no permanent germicidal property is held by the water.

Mr. Parker. I think, Mr. President, perhaps I was at fault in the way I put my two last questions. As I understood the question that was raised by the German engineers, it was if the water might be delivered, when it came from being sterilized by the ozone process, without having first been treated by sand filtration, as I understand it was at Paris. I think the point they were after, though it was not made very clear, was — would there be any toxic properties, or mechanical effects which were unpleasant, produced by the bacteria, the dead bacteria, as it were? And my other question referred more as to whether the water would behave more like a spring water from having a culture introduced into it, or more like a river water. Both of those questions would refer to the toxic properties which might be induced by the growth of the bacteria, rather than to the ozone directly. Have I made that clear, Dr. Soper?

Dr. Soper. I think I understand the point. If the water were not filtered, but were treated with ozone, it would probably not be sterilized, unless it was very clear to begin with. The action of the ozone would be irregular, and a good deal of the power of the gas would be consumed in attacking masses of solid organic matter. As to the production of toxic properties, perhaps some of the experiments that were conducted at Oudshoorn might have bearing. After deter-

mining the sterilizing capacity of the plant, it was determined to test the effect of ozone upon the poisonous products of bacteria, and for that purpose the toxine of tetanus was obtained from the Pasteur Institute of Paris. The toxine was diluted to one fiftieth concentration, and then a portion of it was injected into a mouse. The dose was one half of 1 c.c., as I remember it. The mouse died immediately. The solution of toxine was then subjected to the ozone treatment for ten minutes, after which doses of 1 and 2 c.c. and upwards were injected into mice without ill effects. I should like to answer the gentleman's question as clearly as possible, and if I am not quite on the track, I would be glad to be put on it.

Mr. Parker. I thank Dr. Soper very much for his information. It is exactly what I was after.

Mr. J. C. Haskell.* Mr. President, I would like to ask Dr. Soper why it would not be better to submit water to this treatment before filtration instead of afterwards? If we submitted it to the filtration process afterwards, all of these dead bacteria that have been killed by this treatment would be practically eliminated from the water, and without doubt it is easier to eliminate dead bacteria through filtration processes than live ones. I would like to ask Dr. Soper if he has any data by which he can tell which process is the more beneficial, — submitting the water first to the ozone treatment and then to filtration, or first to filtration and then to ozone?

Dr. Soper. Mr. President, I would reply to Mr. Haskell's question by saying that it hardly seems that the process of treating water before filtration with ozone is to be considered efficient, unless, as I may have said before, the water is very clear. Because, unless we intended to remove color or odor, it would be an irregular process, and sterilization would not be constant. It can be readily seen that small particles of mineral or organic matter afford hiding places for bacteria which it would be very difficult for ozone to reach. The more thorough the mixture of the gas and the water, the more thorough is the process. And in order to kill the bacteria they must be brought in contact with the gas or ozone. If there are particles of solid matter floating about in the water, the gas cannot be readily made to reach the centers of those masses; and if the masses might be conceived to be composed of organic matter, the envelope of organic matter holding bacteria inside would have to be oxidized before the ozone would attack the bacteria. So far as I know, there have been

* Superintendent, Lynn Water Works.

no experiments made on that point, excepting, perhaps, those of Ohlmüller, who pronounced very decidedly that waters which held much organic matter in suspension were difficult to sterilize.

Mr. George F. Chace.* Mr. President, several years ago a paper analogous to Dr. Soper's was read before the Association by Dr. Drown, on the electrical purification of water. The conclusion of Dr. Drown at that time was, that electrical purification of water on the large scale necessary for public water works was impractical. Dr. Soper has dropped a hint that it is either necessary or desirable that there shall be filtration of the water before it is subjected to the ozone process. Now, mechanical purification of water has been shown to be efficient, and if that is the case, what advantage is to be derived from the subsequent use of ozone?

Dr. Soper. The advantages are not merely the benefits which might come from the sterilization of water. That, perhaps, was an important application, as viewed from the standpoint of the people of France and Belgium, where the system has apparently met with approval; but it would seem that important fields for the introduction of ozone lay in the removal of color and odor. If at the same time a reduction can be made in the bacteria which, taking a conjectural case, might come from a filter imperfectly operated, so much the better.

In reply to Dr. Hollis' question as to the amount of ozonized air required for water, I may say that the data I have given as my own for the treatment of Croton water are one cubic foot of air used for the treatment of 25 gallons of water. The contact in that case was not perfect. With an efficient contact, the ozone would be absorbed in the water, and there would be no escape of ozone at the end of the mixture. There was a decided escape of ozone in the experiments I refer to, because it was not found feasible to bring about a sufficiently intimate mixture of the ozonized air and water in the small laboratory apparatus.

The President. Is there to be any further discussion upon Dr. Soper's paper at this time? If not, in behalf of the Association, I desire to thank Dr. Soper for the information he has given us.

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* Superintendent, Taunton Water Works.

THE CONSTRUCTION OF THE FELLS RESERVOIR FOR THE METROPOLITAN WATER WORKS.

BY JOHN L. HOWARD, ASSISTANT ENGINEER, METROPOLITAN WATER WORKS.

[*Read February 14, 1900.*]

Under the provisions of the act creating the Metropolitan Water Board, it was provided among other things that on or before January 1, 1898, the Board "should provide a sufficient supply of pure water for the following named cities and towns of the Metropolitan District and the inhabitants thereof, to wit: The cities of Boston, Chelsea, Everett, Malden, Medford, Newton, Somerville, and the towns of Belmont, Hyde Park, Melrose, Revere, Watertown, and Winthrop." Since the passage of the act the number of places supplied by the Metropolitan Water Board has been increased by the admission of the city of Quincy, and the towns of Nahant and Arlington. Swampscott is also supplied with water, although not a part of the Metropolitan Water District.

For the purpose of furnishing water to the higher portions of the cities and towns on the north side of the Metropolitan District, whose water supply was divided into high service and low service, and to furnish the entire supply for those places where there was no division in the distribution system, it became necessary to build a pumping station and reservoir on the north side to furnish to those places a supply of water similar to that given to the city of Boston and places to the south and west by the Fisher Hill Reservoir and the high service pumping station at Chestnut Hill Reservoir.

In searching for a suitable location for a reservoir on the north side of the city, and considering the necessary requirements of such a site, attention was naturally directed to a large area of land already in the possession of the Commonwealth for a public park reservation, known as the Middlesex Fells. After some discussion and several surveys, an area of land near the southeastern corner of the reservation was selected. It was quite centrally located to the cities and towns of the northern Metropolitan District on the north, south,

FIG. 1. — SITE OF FELLS RESERVOIR AFTER CLEARING.

FIG. 2. — PLACING CONCRETE ON SLOPES.

and west, and on the easterly side only Winthrop, Swampscott, and Nahant are outside the limits of a four-mile circle drawn from that point as a center. Its elevation was above that of any supply in use by these cities and towns, so that no place should be supplied with less pressure than formerly. It was about 270 feet above Boston city base, and was originally an alder swamp (Plate I, Fig. 1), requiring only the excavation of material and the building of five short dams, at as many outlets, with an aggregate length of 982 feet, to turn it into a reservoir of about 42 million gallons capacity, covering 8.52 acres.

While engaged in making a survey of the proposed site, numerous rod soundings and wash borings were made and test pits were dug, in order to furnish a better basis for an estimate of quantities, and also to give the contractor as much information as possible before bidding on the work.

The area covered by this survey was about 15 acres in extent; the area within the proposed dams was about 10 acres, and in this area there were made about 500 rod soundings, 40 wash borings, and 40 test pits, which is about 50 soundings per acre or one sounding for each 900 square feet. On the proposed locations for the dams, soundings were taken at intervals of 25 feet on the center lines, in order to definitely determine the surface of the rock.

Soundings at different points in this swamp showed pockets of mud from 12 to 20 feet in depth below the surface, or to grade 245 and 238, but the soundings on the location of the proposed dams showed rock above elevation 245 in all cases. Before determining on this location for the reservoir, the opinion of a geologist was secured regarding the imperviousness of the surrounding rock, and its general fitness as a reservoir site. After a study of the site and a consideration of the data submitted, it was reported that from a geological standpoint the rock and seams would probably be practically water tight, and that the site seemed a suitable one for reservoir purposes. The report stated, however, that it seemed probable that the surface of the rock as indicated by the borings would be found to be incorrect; that the borings showed a rock bowl on the summit of a hill with no point in the surface of the enclosing rock as low as points in the muck holes inside the bowl, and that if it should prove to be true it would be a curiosity from a geological standpoint. That is, there were pockets of mud in one case down to elevation 238½, but the lowest point shown by the borings on the

line of the dams was at elevation 246. The result vindicated the correctness of the scientific theory and demonstrated again the fact that depending absolutely upon borings for the surface of the rock is not always a wise proceeding. In one place, at the point shown by our borings, with rock at an elevation of 260, it was actually found at 238½, about 22 feet lower than shown.

In Fig. 1 the rock as found is shown by the dotted lines; and the full line shows the rock surface as plotted from the soundings and shown on the contract drawings. The narrow seam of earth shown on the profile of Dam No. 5 is something that could not be expected to be found by borings, but it is somewhat surprising that the profile of Dam No. 2 should show such a variation from the contract drawings. The places where the dotted lines rise above the full lines are caused by slight changes in the location of the dams to avoid seams or rotten rock. These changes will be shown more clearly in Fig. 2.

In Fig. 2 the full contour lines show earth elevations above 271 and the rock contour at elevation 250 as plotted from the soundings. The dotted lines show the location of the dams and the water line as built, and the rock surface as actually found at elevation 250. The 250 contour lines agree as closely as could be expected, perhaps, except at the northwesterly corner of the west basin and on the easterly side of the east basin near Dam No. 4, the greatest variation being about 50 feet. These variations when summed up, however, were sufficient to increase the capacity of the reservoir from 38,500,000 gallons to 41,350,000 gallons, or a little over seven per cent.

The area selected was naturally divided by a point of ledge into two nearly equal parts, and by utilizing this rocky ridge and building two short division walls, one on the south end 108 feet long, and one on the north end 53 feet long, two basins were formed when the reservoir was drawn down six feet, so that when it became necessary to clean the reservoir one basin would be available for use at all times.

In the design of the reservoir it was intended to remove all earth and vegetable matter from the ledge, and to cover the surface of the bottom, and the embankments, with concrete and stone, so that at no point would the water come in contact with anything likely to promote the growth of organisms, or furnish food for them. Several points of ledge extended nearly up to high-water level at different places in the reservoir, and it was thought best to remove all of this rock above grade 265, so as to give a minimum depth of six

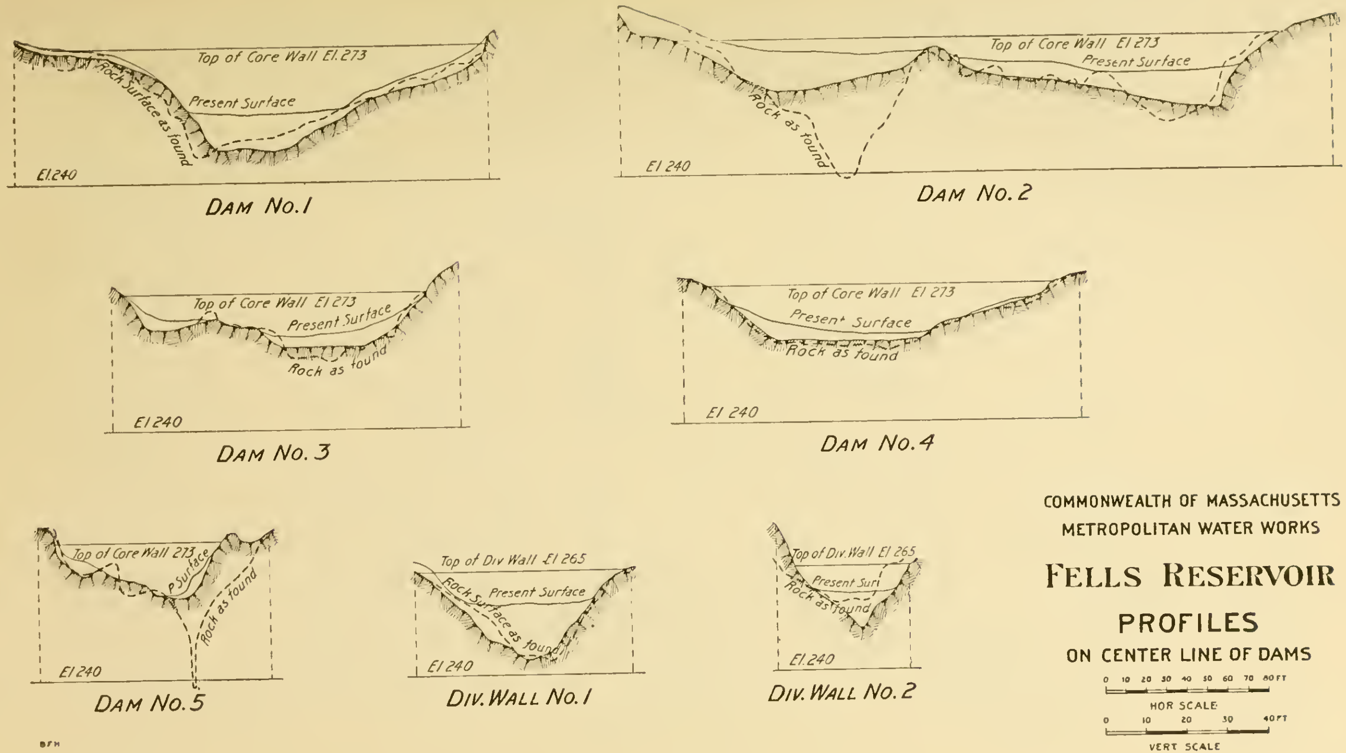
Top of Core Wall El. 273
Present Surface
Rock Surface as found
El. 240
Dam No. 1
Top of Core Wall El 273
Present Surface
Rock as found
El 240
Dam No. 2
Top of Core Wall El 273
Present Surface
Rock as found
El 240
Dam No. 3
Top of Core Wall El 273
Present Surface
Rock as found
El 240
Dam No. 4
Top of Core Wall 273
Surface
Rock as found
El 240
Dam No. 5
Top of Div Wall El 265
Present Surface
Rock Surface as found
El 240
Div. Wall No. 1
Top of Div. Wall El 265
Present Surf
Rock as found
El. 240
Div. Wall No. 2
COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN WATER WORKS
FELLS RESERVOIR
PROFILES
ON CENTER LINE OF DAMS
0 10 20 30 40 50 60 70 80 FT
HOR SCALE
0 10 20 30 40 FT
VERT SCALE

FIG. 1.

feet of water in the basins when full, and do away with shallow flowage as much as possible.

RESERVOIRS AS PARTS OF PARK SYSTEMS.

During the last few years the use of reservoir grounds in the Metropolitan District by the public as portions of the park systems has increased to a surprising extent, and there seems to be no good reason why landscape considerations should not be given more weight in their design. The opening of the various electric lines to the outlying districts, the use of the bicycle, and the development of the boulevards by the Metropolitan and Boston Park Commissioners have all tended to increase the use of reservoir grounds by furnishing pleasant and convenient means of access to them. It is probably safe to say that within the last ten years the use of the Chestnut Hill Reservoir grounds by the public has increased tenfold, and it is by no means improbable that by the time the heart of the Fells reservation can be reached as easily as Chestnut Hill is now by the electric cars, running through parkways, and as this great reservation on the north side of the city becomes better known to the public, this place in connection with Spot Pond will be a pleasure resort for large numbers of people; and for this reason it was thought wise to depart slightly from the usual form of construction in order to improve its appearance and keep it more in harmony with its surroundings.

It is usual in designing a dam to select a point where the quantity of material required for its construction will be the least, and after determining a safe section for the embankment to build it of the required dimensions, and, bearing in mind the fact that a straight line is the shortest distance between two points, to make it usually with straight and even slopes of 1½ to 1, 2 to 1, or 3 to 1; sometimes with a berm to break the slope, if the dam is a high one, but usually presenting to sightseers the outward form of a railroad embankment.

In the case under consideration, it was finally decided to follow the designs of the landscape architects who had already been consulted by the Metropolitan Park Commissioners in their work, as far as possible without sacrificing the essential requirements for waterworks purposes and without adding unduly to the cost of construction. The outlines of the dams were made curved instead of

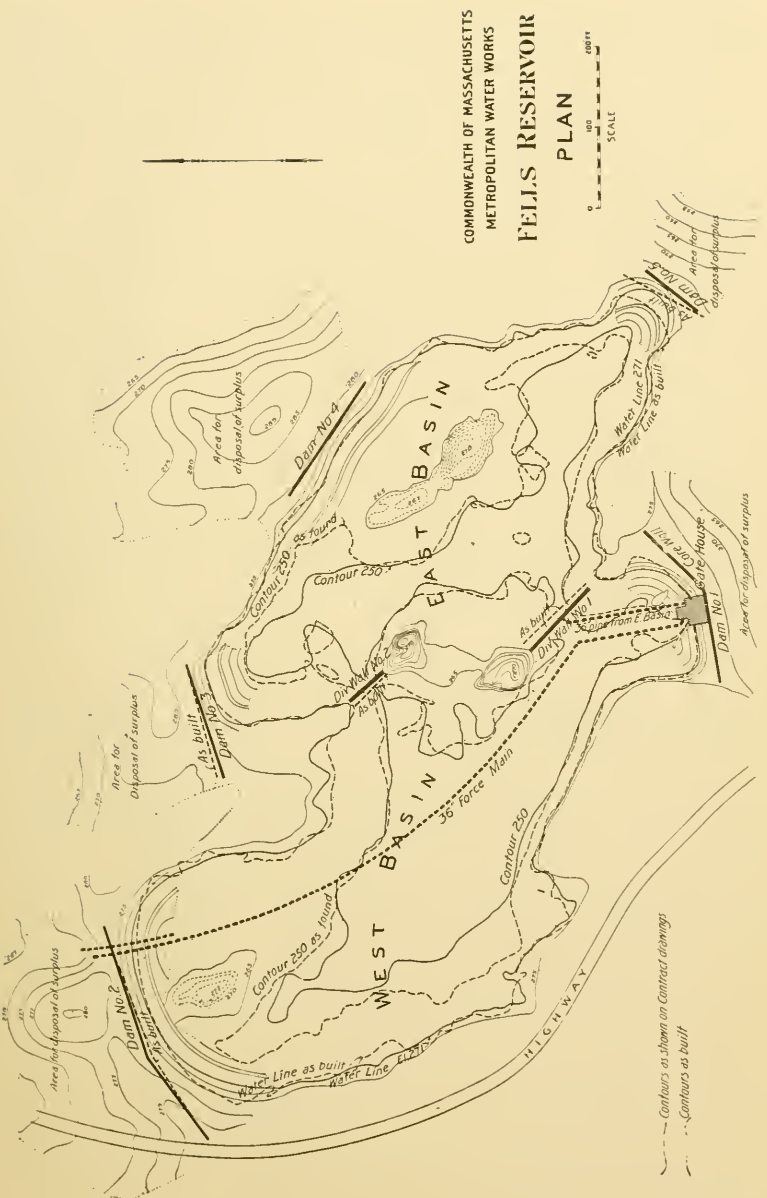
COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN WATER WORKS
FELLS RESERVOIR
PLAN
SCALE
EAST BASIN
WEST BASIN
Dam No. 1
Dam No. 2
Dam No. 3
Dam No. 4
Dam No. 5
Div. Wall No. 1
Div. Wall No. 2
Gate House
Core Wall
36" Force Main
36" pipe from E. Basin
Contour 250
Contour 250 as found
Water Line as built
Water Line El. 271
Water Line 271
As built
Area for disposal of surplus
HIGHWAY
Contours as shown on Contract drawings
Contours as built

FIG. 2.

straight, some with fairly regular curves, others decidedly irregular, and all joining the original rock surface as naturally as possible. There was a large quantity of material to be disposed of, 100 000 cubic yards of earth and 8 000 cubic yards of rock, and in order to better conceal the dams this surplus material was piled in their rear, in one place 25 feet high, and the surface was graded so as to run smoothly and naturally to the original ground.

The supply to the reservoir comes through a 36-inch pipe from the pumping station at Spot Pond. Provision was made for doubling the capacity in the future, by laying a second line of 36-inch pipe through the core wall and dam at the inlet of the reservoir, and through the wall of the gatehouse at the outlet. All water, either entering or leaving the reservoir, passes through the gatehouse.

The site of the reservoir is in a natural woodland surrounded by outcropping ledges on all sides, and the general appearance of the place is decidedly wild and uncultivated, and as if miles away from any considerable population (Plate I, Fig. 1). There was no suggestion of artificial surroundings at any point, and it was the aim of the landscape architects to avoid as much as possible all such appearances in its construction.

CONTRACTS.

The contract was let in May, 1898, to T. W. Kinser & Sons for about $51 400. The price bid for earth excavation was 19 cents per cubic yard, and this included cutting, clearing, and grubbing the ground, all pumping and draining, the excavation of all the material except rock, the building of the rolled embankments, and the final disposal and grading of the material. The contractor stated that he did not expect to make a profit on the earth excavation at that price, and he was not disappointed. The weather was exceedingly unfavorable to the prosecution of the work. Possibly many here remember the kind of a working season it was from May to October, 1898. It seemed to rain about every other day, and in one particular case, after the excavation for a core wall was practically completed, the trench was pumped out three different times on as many days before a start could be made. In October the contractor abandoned the work, and with as little delay as possible the work of completing the construction of the reservoir was re-let, and on November 4 the contract was awarded to Nawn & Brock at a price for earth excava-

tion of 51 cents per cubic yard. This price, while considerably above what has been paid in many places for similar work, has proved none too large in this particular case, and it is probable that if the same contractors were asked to bid on a similar piece of work, their price would be increased over what they received on this.

The bottom of the reservoir was established at elevation 250, which is as high as any of the supplies formerly used in this district, and, as the soundings showed the muck extending down to elevation 238, it was decided to remove all muck below the bottom of the reservoir and refill the space with good material from the excavation, thoroughly rolled in four-inch layers with a heavy grooved roller. In the west basin the amount of muck to be removed below the bottom of the reservoir was estimated at 11 000 cubic yards, all in one pocket, and in the east basin there was about as much more, but distributed over a considerably larger area with three pockets, varying from six to eight or nine feet in depth below the reservoir floor.

The contractor believed it would be more economical for him to take out this muck with a dredge, as it was too soft to shovel into carts, and too low to be drained without pumping, and when he tried to pump it out gave considerable trouble from clogging the suction pipe. At considerable expense he erected a Hayward excavator, which is a grapple dredge with a fixed length of boom, and which loads from one side only. With this dredge he loaded muck through a hopper into cars of about one cubic yard capacity, and then the cars were hauled by a hoisting engine in trains of six to the top of the dump and switched along on the dump to the place of disposal. After several thousand yards had been excavated, the edge of the excavation under the dredge caved, requiring the moving back of the dredge before all of the muck had been excavated, and leaving a considerable quantity in the center of the muck hole that would have to be taken out by carts later. The muck taken out by the dredge was so full of water that after its disposal the dump became a quagmire; and although a platform was built under the track to keep it from sinking, after each shower it required more plank and attention to keep it in line, so that the cars could keep on the track. By this time it was seen that the work could not be completed that season in any event, and after cold weather it was found very easy to remove the muck by carts. A sump hole was kept well down in advance of the excavation, the muck was planked over where it went down too steeply to haul out the loaded carts, and of course in

cold weather, when the ground was frozen, it was no trouble to handle the material on the dump.

The rock excavation was divided into two classes in this contract. It was known that a large number of boulders would be found, and on the exposed surface of the ledge in many places were loose and seamy stones that should be removed; so the rock excavation was classified either as loose rock or solid rock. Loose rock was defined as all boulders or loose rock that measured more than four cubic feet and less than ½ cubic yard, and solid rock was defined as all boulders measuring over ½ cubic yard and ledge requiring blasting for its removal. In this case the contractor was paid for all rock that was taken out, even if it was outside the lines given by the engineer. It was thought that as whatever rock was taken out increased the capacity of the reservoir by 200 gallons for each cubic yard removed, ¾ of a cent for each gallon added to the storage capacity was not unreasonable.

DAMS.

The dams were made with a concrete core wall of Rosendale cement mixed 1 : 2 : 5, 3 feet wide on top and with a batter on each side of 1 in 12, bonded into the solid ledge by a trench from 2 to 3 feet deep. The face of the core wall on the side next the reservoir was plastered with a ½-inch coat of Portland cement, put on in two portions, as follows: next the concrete a thick coating of Portland cement mortar mixed in the proportions of one part of cement to one of sand was put on, rubbed to a uniform surface and left rough; over this was spread a coat of neat Portland cement which was thoroughly worked to make a water-tight surface. The embankment surrounding the core wall was made of selected material rolled in 4-inch layers with a heavy grooved roller, without stones over 4 inches in their greatest dimensions. The embankment was built one foot wider on the side next the reservoir than the dimensions given on the plan, and after it had been well rolled and packed this extra foot was taken off before the concrete slope was put on, and paid for as earth excavation. The embankment was 10 feet wide on top, with a slope on the rear side of 2 to 1, and on the side next the reservoir a slope of 4 to 1 to a point 4 feet below high water, and from there to the bottom of the reservoir a slope of 2 to 1. From the bottom of the reservoir to elevation 267, or 4 feet below high water, the surface of the embankment was covered with a layer of

FIG. 1.—COMPLETED DAM.

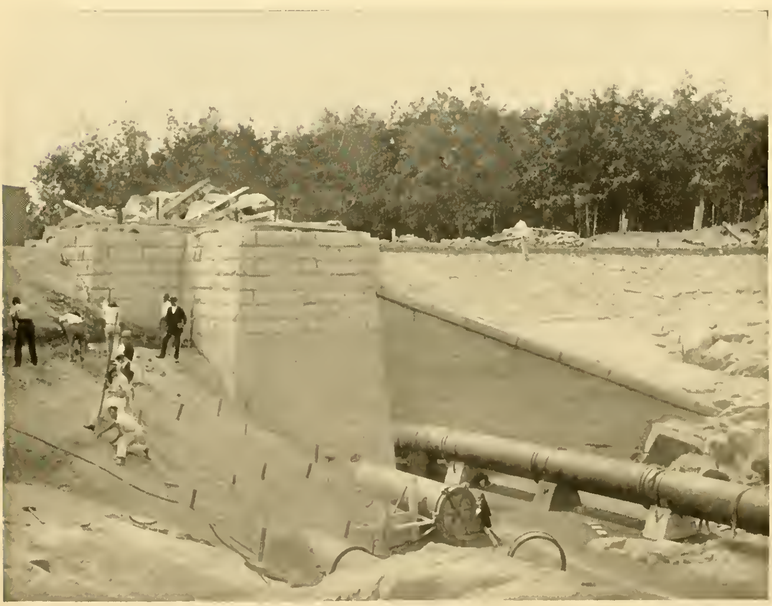

FIG. 2.—GATE HOUSE.

Portland cement concrete 4 inches thick, mixed in the proportions of 1 : 2½ and 4, with a footing course 1 foot square at the bottom. Above elevation 267, to a point 1½ feet above high water, the embankment was covered with a layer of broken stone 10 inches in thickness; the under 6 inches of this covering was broken stone not more than 2½ inches in greatest diameter, and the upper 4 inches, stones not more than ¾ inch in their greatest diameter; all of the stones were free from dust or other fine material.

All of the dams, with one exception, were built in this manner. The one next the gatehouse, however, was made somewhat more formal. The gatehouse of course was plainly the work of man and not of nature, and for this reason the landscape architects considered that an obvious dam with straight slopes and stone paving would not be out of place. So this dam was built with a straight slope of 2 to 1 from the bottom to the top. The concrete extends from the bottom of the reservoir to a point 6 feet below high-water line, and from there to a point 2 feet above high-water line the dam is faced with stone paving 18 inches thick, the bottom layer being of broken stone and about 6 inches in thickness (Plate II, Fig. 1).

In placing the concrete on the slopes, sets of rails consisting of two 2 x 4-inch sticks with a 2-inch stake between them were laid to line and grade not more than 10 feet apart (Plate I, Fig. 2). Then the space between the rails was carefully graded, and concrete put on as dry as possible and still have the moisture come to the surface after ramming. The surface was left about ½ inch below the top of the rails. Then within an hour a mason went over it with a mortar mixed 2½ sand to 1 cement, and smoothed the surface with a trowel. At first the contractor thought he could nail boards across the rails, and by starting from the bottom and ramming the concrete under the planks and adding one plank at a time secure a fairly smooth surface without having to make use of a coat of mortar afterwards. In one or two instances fairly good results were obtained, but generally after the lagging was removed there were so many places that needed smoothing up and patching that it was thought better to do the entire surface the other way and get a uniform result, as well as being cheaper than using boards, not many of which could be used on a second dam, owing to the difference of the radii of the curved surfaces. Possibly, if the surface of the dams had been straight instead of curved, the boards might have worked better.

On the bottom also a layer of concrete 4 inches thick was placed, made of Rosendale cement; it was not intended to be water tight, but merely to prevent the water from coming in contact with earth that might furnish food for the growth of organisms, and to facilitate the cleaning of the basin. The plastered surfaces of the core walls were relied upon to prevent leakage from the reservoir.

The division walls between the basins were made of Portland cement concrete, 6 feet wide on top with a batter on each side of 1 in 8, and extended down to the solid rock, and were bonded into the rock by a trench about 3 feet deep. These walls were not plastered on the outside, but proved practically water tight under heads of 15 feet, which is all they can ever be called upon to sustain.

The 36-inch force main is carried through the reservoir 2 feet above the bottom on concrete piers, to which it is anchored by means of a 2 x $\frac{1}{2}$ inch wrought-iron strap around the pipe connected by rods and turnbuckles with a 4-inch channel iron buried in the concrete (Plate III, Fig. 1). The grade of the bottom of the pipe, 2 feet above the bottom of the reservoir, was fixed chiefly to save rock excavation in the deep cuts in the approaches at either side of the reservoir; it also facilitates the work of cleaning the reservoir, and permits the water to drain freely to the gutter from the sides of the basin. The gutter is V-shaped, 2 feet wide on the top with a maximum depth of 6 inches and minimum depth of 2 inches, and has a fall of $\frac{1}{2}$ inch in 100 feet.

GATEHOUSE.

The original study for this reservoir provided for two gatehouses, one at the inlet and one at the outlet; but after further consideration it was decided to bring the water through the reservoir in the force main to one gatehouse, from which it could be distributed into either basin, or supplied directly to the cities and towns as desired. The substructure is made of Portland cement concrete. The outside walls are 3 feet 4 inches and 3 feet 8 inches wide on the top, with a batter of 1 in 12; the inside walls have a minimum thickness of 3 feet and are vertical. About a foot from the inlet is a set of three grooves for stop planks or screens; 6 feet beyond are openings on either side at elevation 267, governed by stop planks, to be used when it is not desirable to draw water from the bottom of the reservoir; then a few feet further is a weir 6 feet wide, for measuring the

Fig. 1. — Fells Reservoir before Filling.

Fig. 2. — Fells Reservoir, Complete.

flow when desired. Just beyond the weir is a 16-inch overflow pipe, the top of which is set 1 foot above the usual high-water line and connected with a 16-inch drain about 800 feet in length, which discharges into a swamp below the reservoir. The two front chambers are drained by means of 3-inch valves connected by a brass pipe with the 16-inch drain, and the two rear chambers, which will be used in drawing the water from the reservoir when cleaning the basins, have 12-inch valves connected with the drain. A 1-inch brass pipe is laid to each basin and connected with float pipes in the wall of the gatehouse for indicating the height of water in the reservoir on a recording gage. On the rear wall and side wall the concrete foundation extends only to elevation 265, and above that the exposed surface is quarry faced granite masonry.

It will be noticed that a wing wall is shown only on one side of the gatehouse (Plate II, Fig. 2). There was none required on the other side, as the slope from the embankment either met ledge or ran out against the second 36-inch pipe that was built into the wall to provide for an increased future supply. No plastering was done on the walls of the chambers, care being taken to place the finer parts of the concrete next the forms; and after removing the forms the wall came out fairly smooth without showing any stones or cavities on the surface.

The openings in the gatehouse are governed by 36-inch sluice valves operated by hand wheels from the floor. A ratchet wrench is furnished with the valves so that they can be operated by one man under the most unfavorable conditions.

The superstructure of the gatehouse is made of a brown seam-faced stone with granite base and trimmings, and has a tile roof. The inside dimensions on the floor are 27 feet 6 inches × 22 feet 4 inches, with an ell of 12 feet 4 inches × 9 feet 2 inches.

A comparison of the engineer's preliminary estimate of the principal items for the construction of the work and prices for the same, with the prices at which the contracts were awarded, is on page 32.

The amount of the contract using the preliminary estimate of quantities and the prices bid at the first letting was $51 465, and there was paid on this contract $35 038.48. The additional amount of the second letting, using the price bid at that time and the estimated amount of work remaining to be done, was $54 871.50, or $3 406.50 more than the amount of the first bid for the entire work, and there was paid under this second contract $68 836.40.

The total estimate of the engineer for the work was about $103 000, without the superstructure of the gatehouse, sluice valves, and operating machinery, or engineering expenses. The actual amount paid to the contractors on both contracts was $103 874.88; and the cost per million gallons was about $2 500.

METROPOLITAN WATER WORKS — FELLS RESERVOIR.

Comparison of Preliminary Estimate with Actual Quantities and Prices.

		Earth Excavation. Cu. yds.	Loose Rock Cu. yds.	Solid Rock. Cu. yds.	Portland Cement Concrete. Cu. yds.	Rosendale Cement Concrete. Cu. yds.	Portland Cement Plastering. Sq. yds.
Engineer's Preliminary Estimate.	Quantities	100 000	1 000	3 500	1 600	3 500	1 100
	Price	$0.40	$1.00	$2.00	$6.50	$5.50	$0.70
	Cost	$40 000.00	$1 000.00	$7 000.00	$10 400.00	$19 250.00	$770.00
First Contract.	Quantities	54 101	511	5 080	—	1 965.23	691.4
	Price	$0.19	$0.50	$1.75	$5 50	$3.95	$0.25
	Amount Paid	$10 279.19	$255.50	$8 890.00	—	$7 762.66	$172.85
Second Contract.	Quantities	56 750	974	3 370	1 817	2 708	540.0
	Price	$0.51	$0.90	$1.50	$7.00	$5.25	$0.75
	Amount Paid	$28 942.50	$876.60	$5 055.00	$12 719.00	$14 217.00	$405.00
Total, Both Contracts.	Quantities	110 851	1 485	8 450	1 817	4 673	1 231
	Amount Paid	$39 221.69	$1 132.10	$13 945.00	$12 719.00	$21 979.66	$577.85

DISCUSSION.

DR. F. S. HOLLIS.* I would like to say, as something supplementary to Mr. Howard's interesting paper, that it has been my duty to examine the water of this reservoir since it was first filled early in September. Without exception it has been uniformly lower in color and organisms than the water pumped into it, as would be anticipated from the fact that the organisms and the color to a slight extent are decreased by passing through a number of miles of pipe, — in this case, I think, something over twelve miles. With a single exception, which I think was in May, there have been absolutely no local growths in the reservoir since it was filled. There has been no increase, in other words, in the organisms over those put in. From the method of construction, the division of the reservoir into two basins, one of which can be drawn down while the other is in use, and the very clean rock surface and cement bottom, it ought to be possible to keep the reservoir in the most perfect condition as regards the quality of the water stored there.

* Biologist, Metropolitan Water Works.

Mr. Walter H. Sears* (by letter). In connection with this paper, a brief reference to the construction of the dams of the Winchester Water Works, which are in this immediate vicinity and which were built under my direction, may be interesting.

The North Reservoir dam was built in 1873 and 1874, and that of the South Reservoir in 1880 and later.

The north dam, as well as that for the South Reservoir, was built on a curve, as being really the line which required the least amount of earthwork in the embankment. Both dams were built with core walls of stone laid in cement, with a coating of mortar plastered on the water side, and a second coating of neat cement troweled on in a thin layer and then brushed over with a wet brush. This work was done by a skilled mason.

At the south dam a pocket of mud or muck, some sixteen feet deep, was encountered. This muck was entirely vegetable in character, with no stones or gravel except where such may have become mixed in around the sides of the pocket. Incidentally it may be mentioned that the remains of a beaver dam were encountered in this deposit; sticks two inches and even three inches in diameter were found, with the ends sharpened in the manner peculiar to the beavers, still showing the marks of their teeth, although it must have been very many years since these animals lived in this region. These sticks were quite soft when first found, and after a few days' exposure to the air they became full of cracks as the water dried out, so that they could not be preserved.

There was a small brook running through the valley at this time, and it was decided to utilize the same in removing this muck. The stream was dammed temporarily and the water used to bring the muck into a semi-fluid condition, in which state it was allowed to flow into a well or sump, from which it was pumped by an ordinary rotary pump and allowed to flow away down the original channel of the brook or over the ground below the dam site.

* Civil Engineer, Plymouth, Mass.

WOODEN JOINTS IN CAST-IRON WATER MAINS.

BY WILLIAM MURDOCH, ENGINEER AND SUPERINTENDENT,
SAINT JOHN WATER WORKS.

[*Read March 14, 1900.*]

Water was introduced into the city of Saint John, N. B., through a steam pumping plant, in the year 1837. The jointing of the pipes then was mainly in lead. Some rust joints were made also, and they have remained intact ever since. One of these, which had occasion to be broken about two years ago, was found in perfect condition.

When preparations were being made for the abandonment of the pumping system and the laying of a 12-inch gravitation main 4¼ miles in length, the superintendent of the Saint John Works, Mr. Gilbert Murdoch, was sent to Halifax, about the year 1849, to observe the process there adopted of jointing the pipes with wood, in the introduction of water to that city. As a result, the Saint John pipe, which was completed in the year 1851, was jointed throughout with wood, only excepting such joints, mainly in specials and stop cocks, as were either so large, so small, or so unsymmetrical that the staves would not fit.

A 24-inch main was laid in the year 1857 alongside the 12-inch main, and wood was again used, the proportion of wood to lead being about the same as on the preceding occasion.

Another 24-inch main was laid in the years 1873 and 1874. Turned and bored joints had been invented by this time, and a large number, perhaps one half, of this kind were employed. The remainder of the joints were made some with wood and some with lead.

The experience with these joints has been that the wood has proved the most desirable jointing material. Driven dry and well wedged, on absorbing moisture from the water in the pipe it becomes perfectly tight, the only evidence of the presence of water within being in the mere dampness of the end wood exposed. On the pipes contracting and expanding, under changes of temperature, the elasticity of the wood has allowed of a longitudinal shearing to and fro in the fibers,

whilst the surfaces remained in close contact with the iron, and no leakage took place. The proof of this is in the fact that scarcely ever does a leak occur in a wooden joint.

Lead calking, on the other hand, becomes pulled as the pipes contract, and remains out when they expand again in summer. Another pull is given the succeeding winter, and so on until the pressure overcomes the resistance of the lead and you have a blown joint. To be sure, this process takes place only in plain joints. A groove in the socket will overcome this difficulty, but it will also require more lead.

Turned and bored joints enjoyed considerable popularity for some time. For the information of any who have not seen them, it may be stated that such a joint consists of a slightly tapering turned spigot end fitting accurately into a bored or machine-cut faucet or bell. Such surfaces are well smeared with white lead and the joint slammed home. Some have a slight recess left for the addition of lead if thought necessary, but the recess in our case was not grooved ; and the lead where used has often backed out.

The objection to such joints has been that under changes of temperature their rigidity has caused leakage. If laid in warm weather and exposed to the sun, on cooling the pipes shrink and the joints open ; and if laid in frosty weather and later on subjected to heat, a socket will now and then burst. They cost more than plain joints, and for the reasons given seldom remain tight.

All of these considerations prevailed upon the writer to use wood for jointing a 24-inch cast-iron pipe, laid by him in the years 1898 and 1899, for the supply of the western district of the city of Saint John.

The length of the main is 5½ miles, and the deepest depression is 166 feet below the level of the lake from which the head is derived.

All of the joints are of pine, with the exception of specials, stop cocks, and other unstandardized connections into which the staves did not fit. These odd joints are of lead. The pressure has been on and the main in operation for about three months, during which time there has been no trouble of any kind.

The contract price of the staves has been 13 cents per joint, and the cost of labor, laying and jointing, about 57 cents per joint, making a total cost per joint of 70 cents. The rate of wages was $1.20 per day.

It must be borne in mind that before covering a pipe jointed with

wood it is necessary to let in the water and examine every joint carefully for leakage. Where a leak occurs, drive a wedge into the wood either flatwise or crosswise, as may be necessary for thickening or for broadening the stave. Once it is wedged up tightly, and the pipe covered over, no further leakage will occur.

As to the durability of wooden jointing material, the accompanying samples will speak for themselves (Plate I, Fig. 1). That marked *A* was taken from the 12-inch main, about four years ago, after having been in use about forty-five years. *B* was removed after about forty years' service in the 24-inch main. Both have been lying on a shelf in dry air for three or four years, yet their varied experience has not induced decay. Indeed, some joints of iron pipe have decayed where exposed to acids and electric currents in the soil, but wooden jointing material has invariably held its own against the ravages of time.

The stave marked *C* is one of the pattern used last year on the 24-inch pipe, of which the following is the

SPECIFICATION.

1. There will be required by the Board of Management of the Department of Public Works of the city of Saint John,

2 400 joints for 24-inch pipe.
250 joints for 12-inch pipe.
80 joints for 10-inch pipe.

2. A joint in each case shall consist of a sufficient number of staves to encircle the exterior surface of a pipe, and the circumference shall be as follows: —

24-inch pipe, 81 inches.
12-inch pipe, 42 inches.
10-inch pipe, 35 inches.

Each stave is to have a length of four and one quarter ($4\frac{1}{4}$) inches, and a thickness throughout of seven sixteenths ($\frac{7}{16}$) of an inch; the outer and inner surfaces are to be concentric, and the sides radial.

3. Each stave is to conform transversely with the curvature of a circle whose radius shall be as follows: —

For 24-inch pipe, radius $12\frac{7}{8}$ inches.
For 12-inch pipe, radius $6\frac{5}{8}$ inches.
For 10-inch pipe, radius $5\frac{1}{2}$ inches.

4. All of the staves are to be made of clear white pine, straight in grain without knots or shakes, worm holes or rot. No stave will be accepted which does not conform with these conditions, and they must be well seasoned and thoroughly dry.

5. All of the staves must be made to the satisfaction of the engineer and superintendent of sewerage and water works for the time being. He will have authority to reject any that in his judgment do not conform with the conditions of this specification, and his decision shall be final. He shall also have the right to explain any supposed ambiguity and to alter any dimensions named herein prior to or during the course of manufacture of the staves, such alteration not to affect the contractor's right to be paid for those already made ; and it shall be the duty of the contractor to cause such staves made by him or under his direction to have the exact dimensions so given by the said engineer and superintendent, when stated in writing by the said engineer to that effect.

6. The engineer to have the right to increase or diminish the number of joints to the extent of ten per centum above or below the number herein named in each class, giving notice to the contractor to that effect, in writing, prior to the manufacture of the staves ; but should the whole number of any class be made, and the engineer then find that all are not required, the city shall, nevertheless, accept the whole.

A FEW NOTES ON CAST-IRON PIPE.

BY FREEMAN C. COFFIN, CIVIL AND HYDRAULIC ENGINEER, BOSTON.

[*Read March 14, 1900.*]

While in Yarmouth, N. S., recently, I noticed a cast-iron pipe joint that is used there which is different from anything I have used or seen used in the United States.

In this joint the spigot and bell of the pipe are turned as shown in the accompanying sketch (Fig. 1).* This drawing was furnished

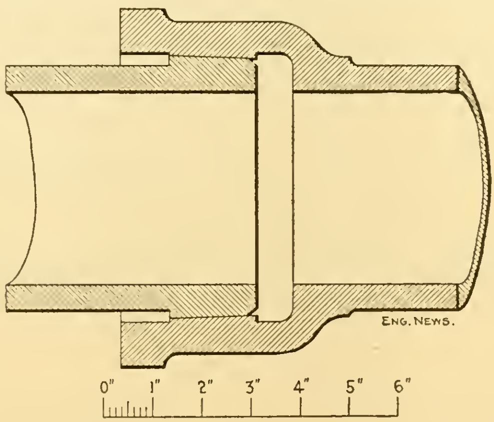

FIG. 1.

me by the Montreal Pipe and Foundry Company, which has a pipe foundry in Londonderry, N. S., where this form of pipe is made. This company informed me that the charge for this pipe was about five dollars per ton more than for the ordinary bell and spigot pipe, which would mean an addition of about thirteen per cent. to the Canadian price of pipe.

The drawing shows a 4-inch pipe with a lead space one inch deep by one fourth inch in thickness. The weight of this lead joint would be approximately 0.15 pound per foot of pipe, with 12-foot lengths, while in the ordinary pipe joint it is 0.5 pound per foot of pipe.

The following table shows that the saving in the weight of lead will not compensate for the extra cost of the pipe : —

* For this cut the JOURNAL is indebted to *Engineering News*.

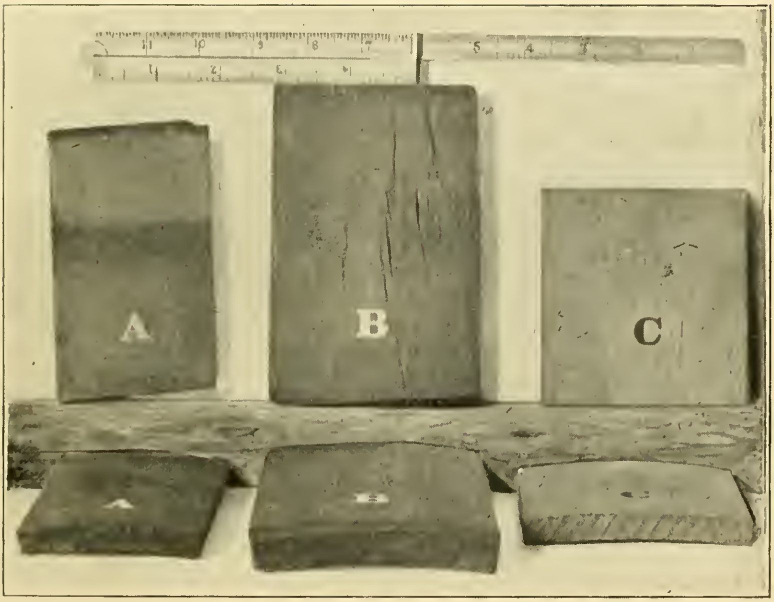

FIG. 1.

COST OF PIPE AND LEAD PER FOOT.

Diameter.	Weight per foot.	Cost, Plain Joint. Pipe.	Lead.	Total.	Cost, Turned Joint. Pipe.	Lead.	Total.	Difference in favor of plain pipe.
4 in.	18 lbs.	$0.241	$0.025	$0.266	$0.271	$0.008	$0.279	$0.013
6 ,,	30 ,,	.402	.037	.439	.455	.011	.466	.027
8 ,,	44 ,,	.59	.05	.64	.667	.014	.681	.041
10 ,,	60 ,,	.805	.055	.860	.91	.017	.927	.067
12 ,,	79 ,,	1.058	.065	1.123	1.195	.020	1.215	.092

The yarn used for gaskets is saved, as well as the time required for driving the same, by the use of the turned joint. The time usually spent in centering the pipe is also saved. The pipe, after being entered and forced home, remains rigidly in place, and there is nothing to do but run and calk the lead.

The turned portions are slushed before leaving the foundry to prevent rusting.

I am informed that ordinary deflections from line can be made as well as with the usual form of joint. It is hardly probable that as great deflections can be made as are sometimes done with the latter.

Mr. George H. Robertson, Superintendent of the Yarmouth Water Works, speaks very highly of the joint, and says that, in his opinion, the extra cost is fully offset by the ease with which the pipe is laid.

This joint certainly has an interest for water-works men.

WEIGHTS OF CAST-IRON PIPE.

The weights of cast-iron pipe adopted by different users and makers of water pipe for the same head or pressure are far from uniform. Many foundries issue cards giving their standard weights for various sizes and heads. From two cards that I have compared I have taken the following weights per 12-foot length for 200 feet head: —

Comparison of Standard Weights of Pipes from Two Foundries.— Pounds.

Diameter of pipe, in.,	4	6	8	10	12	14	16	18	20	24
First foundry	213	364	538	739	949	1232	1496	—	2128	2735
Second foundry	259	432	666	900	1196	1577	1925	2322	2744	3800
Per cent. of difference..	21.5	18.5	23.5	20.5	26.5	28	29	—	29	39

As showing the difference in the practice of engineers, the following table gives the weights of pipe used by the Boston Water Works for 200 feet head, and also those used for many years by the late M. M. Tidd, Civil Engineer: —

Table of Weights used by the Boston Water Works and by M. M. Tidd, C.E. — Pounds.

Diameter of pipe, in.,	4	6	8	10	12	14	16	18	20	24
Boston Water Works ...	260	420	600	815	1050	—	1615	—	2250	2985
M. M. Tidd	218	361	529	723	944	1191	1463	1761	2086	2811
Per cent. of difference..	20	13.5	13.5	12.5	11	—	10	—	8	6

Is such a divergence in practice necessary or desirable? Are those who use the light weights taking a great risk for which they must suffer in increased breakage, or are those who use the heavier weights simply throwing away money on unnecessary iron? There are probably good reasons for using heavy pipe in the business district of the city of Boston, but these reasons do not exist in most places.

This is a serious and important question for a body of men who represent the use of so much cast-iron pipe as do those who compose the membership of the New England Water Works Association to consider. How are they to decide what weight of pipe to use?

The engineer of the Metropolitan Water Board is using a list of weights for 200 feet head that are practically the same as those of M. M. Tidd, given in the foregoing table. Pipe of this weight is called by them Class C. It should be noted that in their list they do not include in Class C any pipe smaller than 12 inches in diameter. I do not know whether or not this indicates that they do not use light weights of the smaller pipe.

The following table gives the Boston weights, those of the Metropolitan Water Board, and of M. M. Tidd, for sizes from 4-inch to 24-inch and for 200 feet head: —

Table of Weights of Pipe for 200 Feet Head.

Diameter, inches.	Boston Water Works. Weight in Pounds.		Metropolitan Water Works. Weight in Pounds.		M. M. Tidd. Weight in Pounds.	
	per ft.	per length.	per ft.	per length.	per ft.	per length.
4	21.6	260	19.1	209	18.2	218
6	35	420	30.4	365	30.1	361
8	50	600	45.2	542	44.1	529
10	67.9	815	62.2	746	60.3	723
12	87.5	1050	80.7	970	78.7	944
14	—	—	100	1200	99.4	1191
16	134.5	1615	123.6	1485	122	1463
18	—	—	—	—	146.8	1761
20	187.2	2250	173.2	2080	173.8	2086
24	248.5	2985	228	2740	234	2811

As the result of my experience and observation I believe that the water pressure has little to do with the breakage of water pipe under

the ordinary conditions that prevail in water works. I omit from this statement such extreme pressures as 150 pounds per square inch and over. Aside from these unusual pressures, I am very firmly of the opinion that the pressure need not be considered in the design of the thickness of water pipes. It should be controlled by other factors. I imagine that many men who handle and lay water pipe will agree with me when I say that any pipe that will pass the test of 300 pounds water pressure imposed upon all pipes at the foundry, and stand transportation and handling until laid, will sustain the water pressure in any ordinary water-works system, no matter what their weight or thickness may be. The critical consideration is at what thickness of shell will the point be found where the saving in weight of iron will be exceeded by the loss due to breakage in transportation and handling. There is another element which should be considered, and that is the place in which the pipe is used, as affected by heavy traffic on the street surface above and the liability of disturbance by excavation in the street for other purposes; or, in other words, the difference between urban and suburban conditions.

I believe that all fine distinctions of classification of water pipe can be abandoned with safety and advantage, and three classes be adopted that will cover all cases in water-works practice: —

1. "Light" pipe, to be used with less than 100 feet head or 43 pounds pressure, or for temporary work.

2. "Standard" pipe, for all ordinary water-works service from 43 to 150 pounds pressure or 100 to 350 feet head.

3. "Heavy" pipe, for all pressures exceeding 150 pounds, and for places requiring strength to resist external stress, such as city streets.

The following table is a suggestion for the weights of such classes for pipe from 4 to 24 inches in diameter.

Table Giving Weights of Cast-iron Pipe from 4 to 24 Inches in Diameter. — Pounds.

Diameter, inches.	Light Pipe.		Standard Pipe.		Heavy Pipe.	
	Weight per ft.	Weight per length.	Weight per ft.	Weight per length.	Weight per ft.	Weight per length.
4	17	204	19	228	22	264
6	27	324	30	360	35	420
8	40	480	45	540	50	600
10	54	648	60	720	70	840
12	68	816	80	960	90	1080
14	85	1020	100	1200	115	1380
16	105	1260	125	1500	145	1740
18	120	1440	150	1800	175	2100
20	140	1680	175	2100	205	2460
24	185	2220	225	2700	270	3240

If some such system could be adopted, it would result in a great simplification of the pipe business. All pipe could be ordered and paid for by the lineal foot with the provision that they should not fall short in weight more than a certain percentage. All questions of long and short tons would be settled, and the inspector would only have to count the pieces and see that the weight marked on the pipe was not less than the minimum.

If we could go a little further and have a set of standard specifications for pipe, much time, expense, and misunderstanding would be saved.

If specifications could be prepared that would receive the sanction of this Association and be known as the New England Water Works Association specifications, they would be a valuable addition to water-works practice. Such specifications need not preclude individual ideas, for if one wished to hold to some peculiar notions of his own, and was willing to take only a fraction of the trouble that he must take at present, they could be simply added to the standard specifications for his own use.

Then an inquiry for pipe could read as follows: —

To the Bell & Spigot Foundry.

Quote prices on 5 000 feet 10-inch Standard water pipe, New England Water Works specifications, delivered in Blanktown.

Yours truly,

Pipe Line.

This would cover every point thoroughly, and could be done by wire at small expense.

Such specifications would tend to introduce uniformity in a line of work in which it is possible and most desirable.

Discussion.

Mr. John C. Chase. The use of cast-iron pipe with what is termed a turned or ground joint was common in England and Scotland some thirty years ago, but I am not aware that it has ever been used in this country. When the Manchester, N. H., Water Works were built in 1872, the force main, which was to be of cement-lined wrought-iron pipe, was provided with cast-iron bells and spigots, and an attempt was made to use a ground joint. No lead was to be used in the joint; but the experiment was not a success and a regular lead joint was substituted. It may be a novelty to some who do not

know about it to be told that the sheet-iron shell was put into the mold, and the cast-iron bell and spigot cast around it. What condition it is in at the present time I do not know, but perhaps our friend Walker can tell us.

Mr. Charles K. Walker. It has worked well so far.

Mr. Chase. This is the only case I am aware of where pipe of that description has been used. As I remember it, it was on the lower third of the force main, where there was something like one hundred feet pressure.

Mr. Coffin. I omitted to state that this pipe of which I spoke in the paper was originally introduced into the Provinces from Scotland. It is termed a turned joint and not a ground one, and is not intended to be tight, but only to do away with the gasket and to center the pipe.

Mr. Chase. I believe the original Scotch pipe dispensed with the lead entirely. Is not that your understanding?

Mr. Coffin. That may be true; but the information I received was that this particular pipe was brought first from Scotland and then copied in the Londonderry foundry.

Mr. Chase. In the case I have mentioned it was proposed to dispense entirely with lead, using instead a turned joint, and have the pipes driven together tightly enough to prevent leakage; but the experiment was not a success.

CEMENT-LINED SERVICE PIPES.

BY FAYETTE F. FORBES, C. E., SUPERINTENDENT, BROOKLINE, MASS., WATER WORKS.

[*Read February 14, 1900.*]

Of the many problems which confront those who design and maintain systems of water works, perhaps no one is more perplexing than that of selecting the right material for service pipes.

The choice must lie between some kind of protected iron and lead, for plain wrought-iron pipes are completely stopped up in a few years by the formation of rust, and the water which is drawn through them from the first is more or less discolored and thereby rendered unfit for laundry or other domestic purposes.

There are several ways of attempting to protect the wrought-iron pipes from the oxygen in the water; but with the exception of a lining of lead, tin, or cement, the processes have a doubtful value in prolonging the life of the pipes for the purposes for which they were designed, beyond a few years.

It seems to the writer that, with our present knowledge, it is not wise to use lead in the great majority of cases for several reasons, although it has the advantage of being easily carried over, under, and around obstructions, and resists the corrosive action of some soils much better than wrought iron. It is well to bear in mind in this connection, however, that the water supplied any city or town may change with varied conditions, or perhaps it may be necessary to obtain a supply from an entirely new source, and the new water may attack the lead freely and thereby cause an injury to the health of the people using it.

An experience of twenty-six years has convinced the writer that cement-lined wrought-iron pipe can be made, and the lengths put together in such a way that a very excellent service pipe is obtained.

Pipes have been removed during the past year in the Brookline plant which have been in use for twenty-five years, and no accumulation of rust was found on the inside of them, and the water way was as clean and perfect as the day the pipe was laid ; and moreover several have been removed during the past years and all tell the

same story. I might state further that for twenty-five years not one cement-lined pipe used in Brookline has failed to deliver its supposed quantity of water, when demands have been made on it, and in addition to this continuous freedom of flow, the water is always free from rust unless some disturbance has occurred in the street mains, for which, of course, the service pipes are not responsible.

I do not believe that the conditions in Brookline differ greatly from the conditions in most other cities and towns, and I must think that our success with cement-lined service pipe is owing in a large measure to the care taken and skill employed in lining it.

From an economical point of view, a pipe of this kind takes first rank. The total cost of preparing and lining a one-inch pipe, including cement, never exceeds one and one-half cents per foot. Last year the total cost of one-inch pipe lined and piled up, was four and two-tenths cents per foot. This year, however, owing to the great advance in the price of iron, it will be about eight and two-tenths cents per foot.

This cost is given at this time that a comparison may be made to-day with a three-quarter wrought-iron pipe differently protected from rust, which gives about the same capacity when new as a one-inch cement-lined pipe.

Cost of	$\frac{3}{4}$-inch	tin-lined	pipe	is	about	$0.325
,,	,,	$\frac{3}{4}$,,	,, ,, lead	,,	,,	,,	.48
,,	,,	$\frac{3}{4}$,,	lead-lined	,,	,,	,,	.13
,,	,,	$\frac{3}{4}$,,	enameled	,,	,,	,,	.11
,,	,,	$\frac{3}{4}$,,	galvanized	,,	,,	,,	.08
,,	,,	1 ,,	tarred	,,	,,	,,	.066
,,	,,	1 ,,	cement-lined	,,	,,	,,	.082
,,	,,	$\frac{3}{4}$,,	lead	,,	,,	,,	.225

It seems to me that a description of the whole process of lining may be of interest to the members of the Association, and I will state it as briefly as possible. Our manner of procedure is as follows: —

PIPES.

Our departure from the usual custom begins with the buying; we specify that the lengths shall be about sixteen feet long and also of standard weight. A pipe eighteen or twenty feet long cannot be lined with the same degree of success which can be obtained with pipes somewhat shorter; and our experience has taught us that pipes

about sixteen feet long give the best results. I might add that we find no difficulty in buying pipe of the shorter lengths, and neither is the cost increased thereby.

After the pipes are delivered at our shop, we first straighten all which are much bent. The couplings are then removed, turned around, and screwed on the other end, in order that there may be no trouble in putting the lengths together when lined. The pipes are then carefully examined in order to make sure that no defect exists in the welds or other parts of them. The next step is to run a cutting tool slightly smaller than the inside diameter of the pipe through each length to remove all dirt, scales, and projections of iron from the welds. The pipes are now ready for lining.

LINING.

No sand should be mixed with the cement. Portland cement is not fit for this work, being too heavy and liable to fall from the sides of the pipes before setting. We have used the F. O. Norton brand with great success; but any good American natural cement, which does not set too rapidly and is freshly ground, can be used with confidence. It is very necessary to sift all the cement through a moderately fine sieve, as we find that even the best cements contain small pieces of unground rock and other substances which interfere seriously with the lining. It is also extremely important that the cement should be used quickly after wetting.

When lining, we have one man who does nothing but mix the cement, usually preparing enough for five or six pipes at one time, and constantly working it over to keep it at the right thickness. If a little of a batch is left, we prefer to throw it away rather than to mix it with the next lot.

The press used for filling the pipe is made by the Union Water Meter Company, of Worcester, Mass.; in fact, they make the whole outfit, including cones, etc. It is necessary to fill the pipe entirely full of cement, and a little should be allowed to run out of the farther end. More of the cement will be pushed out by the cones, but this can be returned to the mixing-box and used again, with the exception of that from the last pipe filled from the batch, which is thrown away.

In every case the cones are passed through the pipes twice. A handful of cement is pushed into the pipe before the cone enters the second time; and while it is being drawn through, the pipe is slowly

revolved to keep the cone in the center of the pipe. We endeavor to keep the cones as near the center of the pipe as possible; we find, however, that the practical results are the same if the lining is quite uneven.

The cones are thoroughly washed after each pipe is lined; before they are drawn through, a piece of pipe from twelve to eighteen inches long is screwed to each end of the pipe to be lined, so that the lining at the end will be perfect.

After the pipes have been lined from three to five days, or until the cement has sufficiently set, a thin gruel of cement is run through them. This is done by elevating one end of the pipe and pouring the gruel in from an ordinary watering pot. A rubber cone is now drawn through, which leaves the inside of the pipe smooth and quite impervious to water. The ends are now reamed out to fit the composition ferrules and the threads cleaned. This completes the process, and the pipes are piled away for use.

The number of feet of pipe of different sizes, lined and grouted by one barrel of cement, is as follows: —

1	inch pipe,	700 feet.
$1\frac{1}{4}$	,, pipe,	500 ,,
2	,, pipe,	300 ,,

COST.

In 1898, the cost of labor, cement, etc., for lining 3 000 feet of two-inch pipe and 9 000 feet of one-inch pipe was as follows: —

Labor, preparing pipes	\$65.79	
,, cementing	66.65	
,, grouting	22.66	
,, reaming	39.98	
23 barrels cement @ \$1.10	25.30	
Coal for heating shop	6.00	\$226.38

Which gives the cost of lining two-inch pipe 3.03 cents per foot, and cost of lining one-inch pipe 1.5 cents per foot.

NUMBER OF MEN REQUIRED.

Two men usually get the pipe ready for lining, but during the process of lining, six men are found to be the most economical number to use, distributed as follows: one man mixing the cement, one

man filling the press and overseeing the work, one man working the press, one carrying the pipes to the press and from the press to the coning-frames, and two men, one at each end of the pipe, doing the coning.

In one day, these men will line from four to five thousand feet of pipe.

JOINTS.

A few words describing the ferrules we use at all joints; these are made of the best steam metal, five-eighths of an inch in diameter on the inside, the outside tapering slightly towards the end. They are of two kinds, called by us a double and a single ferrule. The double ferrules are used where the pipes are screwed together, and the single ferrules where the pipes are screwed into the sidewalk stops and connections at the main, which are made with a shoulder at the end of the thread to hold the ferrules in place.

When the service pipes are laid in this way, no unprotected iron exists anywhere on the whole inside, and we feel that we have a pipe which will give as good a water in the house as runs in the street mains outside.

BENDING.

It has often been stated that the cement-lined pipe cannot be bent without injury. We find, however, that the pipes can be bent to any reasonable extent, without any damage to the lining, if this is done with care.

Discussion.

Mr. Charles W. Sherman.* When Mr. Forbes speaks of two-inch pipe and one-inch pipe, does he mean the diameter before lining or after?

Mr. Forbes. When I speak of two-inch pipe and one-inch pipe, cement-lined, I mean what is commonly called two-inch pipe and one-inch pipe. In lining an inch pipe the bore is reduced to about three-quarters of an inch, and a two-inch cement-lined pipe is about an inch and seven-eighths in diameter. It lessens the diameter a little less than a quarter of an inch. We use an inch pipe where they ordinarily would use a three-quarter wrought-iron or three-quarter tin-lined or lead-lined pipe. The price I have given here, you

*Assistant Engineer, Metropolitan Water Works.

understand, is for an inch pipe in comparison with three-quarter lead, and three-quarter wrought iron.

Mr. Frank L. Fuller.* I would like to ask Mr. Forbes when he puts this double ferrule in, where he joins two pieces of pipe together, whether there is any cement put in, or whether it is just slipped in and allowed to fit as it will after it has been reamed out.

Mr. Forbes. For a great many years we have used nothing. We did use cement at one time, but we find the ferrule packs in so solidly that before the rust from the end of the pipe can get to the end of the ferrule it has made a complete dam for itself. It is in very tight, anyway, the reamer being but a very little larger than the outside of the ferrule; we have to drive it in, and I have never found the rust quite to the end of the ferrule.

Mr. Fuller. Is there any trouble in screwing up the pipe? Does that jam the ferrule into the old cement in the pipe and fracture it at all? Have you had any trouble from that?

Mr. Forbes. No; we have n't had any trouble in that way.

Mr. Fuller. Mr. Billings, of Taunton, devised a scheme, filling his couplings with lead, and putting in a German silver ferrule, which was aimed to accomplish this same result. I presume that it may have been described in our papers. It does not seem to me, however, that it is as cheap or as well fitted for the purpose as the one Mr. Forbes has described. As connection was made, the little German silver ferrule slipped inside of the cement; but if the cement lining was n't exactly concentric with the pipe, that is, if the thickness was not exactly the same on each side, the ferrule was very liable to get bent up, and to fail to accomplish the result aimed at.

Mr. T. H. McKenzie. I would like to inquire of Mr. Forbes whether any concern makes this pipe and puts it on the market, or whether every man must line his own pipe.

Mr. Forbes. I don't know of any one who has it for sale, although there may be some one who does. You need to use great care all the way through the process of lining, particularly, to keep everything clean. When we first began to line, years ago, we did n't look over our pipes, and every now and then we would find pieces of iron in them, which prevented the cone passing through, and consequently, the cement mixed up would spoil, and time was lost. Now we have everything all right before we begin. Sometimes the couplings are jammed, but by taking the coupling off the end of one

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* Civil Engineer, Boston, Mass.

pipe and turning it around and putting it on the end of another one, we are sure that the thread on the pipe is all right, and the thread in the coupling also. We at first cemented our pipes without sifting the cement. And you will be surprised, with our best cement, even, how many little unground pieces of rock you will find, and there is also more or less paper and more or less wood which comes from the barrel; and we find that by sifting the cement it works very much better. If we don't do that, little pieces of stone or wood are liable to get on one side of the pipe, and may make the lining very uneven, or perhaps take it all off on one side of the pipe.

Mr. McKenzie. How would the price of a one-inch cement-lined pipe compare with the price of a three-quarter inch unlined pipe?

Mr. Forbes. These prices, of course, are only for the sake of comparison, because they vary from year to year and almost from day to day. A galvanized pipe to-day will cost about eight cents a foot with the best discount I can get, which is fifty, ten and five per cent. from the list. An inch pipe, with the same discount, cement-lined, will cost to-day 8.2 cents a foot; that is the price of the pipe and the cost of lining, including the cement. In other words, it would cost two-tenths of a cent per foot more than galvanized pipe, one costing 8 and the other 8.2 cents.

Mr. McKenzie. A one-inch galvanized pipe before it is lined costs 8.2 cents?

Mr. Forbes. No, we don't line galvanized iron pipe; we line plain pipe. A three-quarter inch galvanized pipe to-day would cost about 8 cents a foot, and a one-inch plain pipe lined would be 8.2 cents to-day. The cost is in effect less than it appears, for this reason: we do most of this work through the winter, with the same men we employ to look after the hydrants, and other things connected with the maintenance of the work. When we have a cold spell they are on the hydrants, and when we have a mild spell we put them to work preparing this pipe.

Mr. Sherman. I would like to ask Mr. Forbes whether he has ever noticed any difference in the frictional resistance; if it is appreciable between the flow through a cement-lined pipe and an ordinary wrought-iron or lead pipe.

Mr. Forbes. I have n't made any experiments in that line, but if you examine the inside of these pipes you will find they are always smooth. Take any kind of enameled pipe that I have ever seen, or galvanized pipe or tarred pipe, and after a few years you will find

a great many little bunches of rust along on the inside, which must interfere with the flow. A cement-lined pipe being always smooth, of course offers no more resistance, practically, than a lead pipe.

Mr. Sherman. Another question relates to a trouble which may not occur in Brookline on account of the character of the water; but as far as I have been able to notice whenever a cast-iron pipe is cut in Boston we find a slimy growth of polyzoa on the interior of the pipe; and I would like to know whether that has been noticed in the cement pipe.

Mr. Forbes. I have never noticed it, and in fact I have never noticed a growth of that kind in Brookline any way; because our water, coming as it does from wells and stored in a covered reservoir, does n't contain anything for them to live on.

Mr. Fuller. I would like to ask Mr. Forbes if he makes any protection at elbows and T's in this way.

Mr. Forbes. We rarely use any elbows or T's. If we have to use a turn smaller than we think best to bend the pipe around we use a short piece of lead pipe, perhaps a foot long, with a coupling on the end like that I passed around, and in making the connection we use ferrules.

Mr. Fuller. Is this cement pipe used much in houses?

Mr. Forbes. No; it is n't used very much inside. In fact, we don't sell this pipe to private parties, except where we lay it in the ground. It is n't on the market. It is rather clumsy to lay inside when you cut joints.

Mr. Fuller. What is used inside mostly, — lead?

Mr. Forbes. We use a great deal of iron pipe in Brookline, and some lead for hot water.

Mr. George F. Chace.* I should like to ask Mr. Forbes how many complaints he has during the year of poor service, — that people can't get a full supply of water.

Mr. Forbes. We never have any on cement-lined pipe.

Mr. Chace. Cement-lined pipe has been used in Taunton since 1876, and during the past year we had 119 such complaints, — cases where we had to take the pipe out. Now, I agree with Mr. Forbes that it is perfectly feasible to line the pipe, and there is no special difficulty about bending the pipe. We can make a cement-lined pipe a good deal better than the specimen shown here, and Mr. Forbes says he can now. The trouble we have is largely in the fittings.

* Superintendent, Taunton Water Works.

Some gentleman, a little while ago, alluded to certain fittings designed by Mr. Billings. I can say they are a complete failure, because I have taken out one of those couplings and examined it, where the thimble or ferrule had been put inside, and the nickel plating of the brass ferrule had come off, and the coupling was half full of rust, where the water had got at the iron, somehow. That was a complete failure, and we have stopped using it, and gone back to a plain coupling. This which has been exhibited here this afternoon may be better than that; but I measured one of these ferrules just now and found it was only a half an inch capacity at the end, and that is reducing the opportunity for a full flow of water, it seems to me.

Mr. Forbes. That is about the same diameter as the inside of the corporation cock is supposed to be. And one reason why I adopted that composition ferrule was, that we never have a corporation cock or a sidewalk stop filled with rust, except where an iron pipe is screwed into it; and I thought if our corporation cocks and our sidewalk stops were rust proof, the same metal would work equally as well when placed in a coupling, and I have found that it does. I know that various kinds of ferrules of tin and lead have not proved successful; and I think one reason for that may be that they are rather weak, and when you screw them together they become bent in revolving the pipe. That is, the cement lining may not be quite in the center of the pipe, and when you turn the pipe around, a lead ferrule may be bent out of shape, and the rust may get in back of it and eat its way in. But our couplings, which are of just the same kind of metal as the sidewalk stops and corporation cocks, have given us very good service.

Mr. H. G. Holden.* I would like to inquire what kind of pipe is in general use in Brookline for inside work.

Mr. Forbes. They usually run an iron pipe to the sink, very often enameled pipe, and in some few cases galvanized pipe, and in some cases tarred pipe.

Mr. Holden. Do you have any trouble?

Mr. Forbes. We do. We have to take them out quite often, but they are where we can get at them quickly and it can be done easily. I suppose in a house piped twenty-five years ago all the iron pipe has now been removed. They usually run lead from the kitchen up to the bath room.

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* Superintendent, Nashua Water Works.

Mr. George A. Stacy.* I would like to ask Mr. Forbes if he protects the outside of his pipe with anything.

Mr. Forbes. No; I used to give them a bath of tar years ago, but I have given that up now. We all know, or at least we find it so in Brookline, that a wrought-iron gas pipe will very rarely rust through from the outside. You will find them in the ground without leaking after years and years and years. This sample which I have passed around, you will notice is covered with a coating of dirt and iron oxide, which forms around the pipe and seems to protect it. And I have reasoned that if a gas pipe would stand for years without rusting through from the outside, a water pipe would stand as long, and so far we have had no trouble at all.

Mr. Chace. That reminds me that my foreman showed me yesterday a piece of pipe, just about as long as the piece exhibited here, and the coating of cement on the inside was perfect, but the outside of the pipe was half gone.

Mr. George E. Winslow.† Are you troubled with electrolysis there?

Mr. Chace. I don't think so.

Mr. Stacy. We have used cement-lined pipe for a number of years, and have a number of miles of it in now, and my greatest trouble from it has been from the iron rusting out. There has been no trouble with the cement, and I don't know why there should be, for that is as durable as rock itself. We thought first of grouting it, but after a while we thought that did n't do any great good. In handling the pipe it is bent more or less, unless you are very careful; and then, in laying it in the trench, in a place like our city, we have to go around a number of obstructions; there are a good many bowlders and rocks, and one thing and another, and we have to have a good many bends. I can't conceive how you can bend a cement-lined pipe without fracturing the lining. The cement won't come off, because it is arched and locked in there, and it is almost impossible to take it out without destroying the pipe; but at the same time you will fracture the cement, unless you have a cement which is elastic, which is a thing I never saw. My experience has been that you have got to handle a two-inch pipe a little more carefully than you have an inch pipe on account of the larger arc of the pipe. I can conceive that if you should put an eighth of an inch of

* Superintendent, Marlborough Water Works.

† Waltham, Mass.

cement into an eight-inch pipe, the arch would n't be enough to lock it so it would n't drop out; but it is almost impossible to knock the cement out of a three-quarter inch pipe without destroying the pipe.

We have used lead pipe inside the houses for our best plumbing for years, and, as far as I know, we have never had any bad effects from it. If you can get a cement-lined pipe which will stay where you put it and stay there forever, as Mr. Forbes seems to think, and you can use no other kind of pipe with perfect safety, it seems to me you have no choice in the matter. I don't know of any coating that you can put on the outside of a wrought-iron pipe that will thoroughly protect it. Of course there is great difference in soils, and I should judge the soil in Brookline was very favorable for the laying of wrought-iron pipe. There are lots of places in my city, however, where iron pipes that have n't been laid over fourteen years have rusted out completely. And while a pipe might hold gas, it does n't follow that it would hold water, because the water is of course under a good deal more pressure. I have had to abandon cement-lined pipe for the reason that we have not yet been able to find anything to protect the outside of it. A cement-lined pipe is certainly the cleanest thing we can use. I suppose the ideal pipe would be glass, if it could only be made so we could handle it. But, as I say, my trouble has been with the iron giving out, and not with the cement. The cement we find just as good as it was at the time the pipe was put down, but the iron won't stand in our soil in a good many places. We have taken some out which have been in good condition, while others, which have been perhaps in the same street, have been completely gone.

Mr. Forbes. I might say that there is a good deal of pipe on the market that is light weight. Of course they don't say anything about the weight, and unless you specify that the pipe must be of standard weight you will be very apt to get it light. We buy at the mills and have it shipped to us by the carload. If you buy it out of stock, it is likely to be made of poor iron, and it won't stand the effect of rust as it ought to.

A Member. I would like to have Mr. Forbes inform us, if he will, how he makes his connections with the street mains, — whether he puts the pipe directly into the corporation cock, or whether he uses a lead connection between the cement-lined pipe and the main.

Mr. Forbes. We use a piece of lead pipe, twelve or thirteen inches long, with a coupling soldered on.

Mr. Winslow. Mr. Forbes says that iron pipes are light weight, and I have found that not only true of iron, but of steel. I think perhaps the difference in the metal has considerable to do with the way both iron and steel pipe will stand in different soils. I have generally found iron pipe of standard weight, and have never had any trouble in getting it when I have asked for it; but steel pipe is usually very thin, and I think perhaps it is of such a nature that it shows the action of the soil quicker than iron does.

Mr. E. A. W. Hammett.* One question has been asked here which I have not heard any answer given to yet, and I am not sure that I can say anything on the subject which will be of special interest. The question was asked by one of the gentlemen whether cement-lined pipe was used in houses. I would say that I know of at least one case where it has been used, and that is in my own house. When, some years ago, I was living in Newton, we put in at first tarred pipe, and within four years' time it became so plugged up with rust that we could n't get any water through it. We then took out all the pipe from the street to the house, about one hundred and sixty feet, and a portion of the piping in the house, and replaced it with an inch pipe, lined with cement. That was about sixteen years ago, and at that time I knew nothing whatever about a ferrule in making connections, so we used simply the ordinary fittings with no lining. But I have had no trouble whatever, since we put in the new pipe, in getting a full supply of water, and have seen no signs of rust in the faucets. We use a cement-lined pipe up to the kitchen sink.

Mr. Edwin C. Brooks.† I would say that the principal trouble we have is the stopping up of the corporation cocks in the mains. What we call rust is really a form of tuberculation which takes place over the opening into the corporation cock, and we have more trouble with that than we have with the supply pipes. But, after all, it seems to me that the whole question resolves itself into the question of the character of the water. With Fresh Pond water, as it was formerly supplied to Cambridge, the supply pipes would last and remain clean for years, as the water was hard, and very slight tuberculation took place. But since the introduction of Stony Brook water, which is very much softer, we get a very much more rapid growth of tubercles, and we find sometimes on removing the cor-

* Civil Engineer, Boston, Mass.
† Superintendent, Cambridge Water Works.

poration cocks from the mains that they are filled over solid, almost, so that there will be only perhaps a hole as large as an ordinary straw leading to the cock. And I have known numerous cases where a family has been supplied with water, without any complaint whatever, where the hole through this formation of tubercles has not been more than a quarter of an inch in diameter.

Mr. Chace. Mr. Forbes says he has never been troubled with pieces of cement getting into the meters. It is not an uncommon thing for us to find pieces of cement in the meters. I suppose he, as well as all the rest of us, is obliged to cut his service pipes once in a while, and I should think it would be almost impossible that there should not be some crumbling of the cement when you cut the pipe, and probably the particles that we have found have come from such places as those. That is one obvious objection there may be to the use of cement lining, if we could find anything better.

Mr. R. J. Thomas.* I will state that recently I had occasion to go around and visit a number of superintendents, trying to get some ideas about service pipe, and I found that there was quite a difference of opinion among them. In fact, my inquiries left me in doubt as to whether there had yet been devised any kind of a pipe which was fit to conduct water. I waited on Mr. Forbes, who, I think, has given the matter very careful attention, and was very much impressed with the way in which he lined his pipe, and I have no doubt that he has been entirely successful with it. On the other hand, other superintendents found a good deal of fault with cement-lined pipe. I also found quite a strong objection to the use of lead pipe, especially five-eighths and half-inch sizes. I was told that it not infrequently filled up with vegetable growths, or sediment of some kind. And I also found that some superintendents had had a good deal of difficulty with the goosenecks or lead connections of the iron pipe filling up with sediment. It seemed to be the general result of experience that a five-eighths or half-inch lead pipe, and in some cases a three-quarter inch, had not worked well in use. I think the Association ought to appreciate the very courteous manner in which Mr. Forbes has answered all our questions, and that he deserves our thanks.

Mr. Chace. Have any of the members present had any experience in using tin-lined pipe?

Mr. Winslow. I know of a tin-lined pipe which was put in in 1873, and it is still in use.

* Superintendent, Lowell Water Works.

Mr. John C. Haskell.* Mr. Chace himself has had some experience with tin-lined pipe, and perhaps he will tell us about it.

Mr. Chace. We have been using it five or six years, and I don't see any reason to change. I am perfectly well satisfied with it, except that it costs too much.

President Byron I. Cook.† I presume, gentlemen, this question resolves itself right down into each one of us using the pipe which fits his own case best, and it is a matter of experiment to tell which is best for any particular locality. I think myself that, with a surface water supply, lead pipe under ordinary conditions will prove as satisfactory as any. In regard to trouble with stoppage at the main, I have experienced some of that myself, and the way I get over it is by having the corporation go through the cast-iron pipe at least a half to three-quarters of an inch. I have never had any trouble from a corporation sealing over with tubercles when it went through the main that far, but when it has been flush on the inside I have. I have found one completely stopped and another within ten or fifteen feet of it would be completely open. I think the experiments which have been conducted by the Massachusetts State Board of Health in regard to lead poisoning have demonstrated that for ground water supplies some other kind of pipe than lead should be used for the services. If Mr. Forbes has solved this problem, which Mr. Chace rather doubts, apparently, then Mr. Forbes is of course satisfied, and Mr. Chace is still open to conviction as to what is the best for him to use.

Mr. Fuller. I don't know whether Mr. Forbes has told us how long he has used these ferrules. He has spoken about using the pipe for twenty-five years or more, and I would like to ask him how long he has used this particular form of ferrule in his connections.

Mr. Forbes. The very first pipes we laid did n't have any ferrules, but I believe we have used these now, probably, in the neighborhood of eighteen years. I don't know of any other place where there is a ferrule like this used, and we had our own patterns made. I might say that I think this year the single ferrule costs about three cents apiece and the double ones about four and a half cents apiece. Of course they are a great deal higher now than they were last year, on account of the higher price of copper composition.

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*Superintendent, Lynn Water Works.

†Superintendent, Woonsocket Water Works.

A VERY BRIEF DISCUSSION OF LEAD POISONING, CAUSED BY WATER WHICH HAS BEEN DRAWN THROUGH LEAD SERVICE PIPE.

BY FAYETTE F. FORBES, C. E., SUPERINTENDENT, BROOKLINE, MASS., WATER WORKS.

[*Read February 14, 1900.*]

Of course it is understood that the writer is not a chemist, and in this brief discussion, the information which he has comes from a study of the work done by those who are competent and have the facilities to make investigations in this direction, and I say these few words in this connection simply to give expression to some of the thoughts which these studies have suggested to me, in hopes that these suggestions may bring the subject more vividly to the attention of the members of this Association, and thereby cause more consideration to be given to it. In the first place, I would ask all interested in this matter to carefully read the Report of the Massachusetts State Board of Health for the year 1898. I do not know any other volume which will give so much up-to-date, practical knowledge on this subject. Allow me to quote from page 32 of this report, that the importance of the subject may be better understood: "It has been found that many waters, when brought into contact with lead service pipes, as in lead distribution pipes, dissolve lead from the pipes, and the water thus becomes dangerous to those who drink it. While the quantity of lead dissolved may be small, and a single dose might not harm the user of the water, the continued use of water containing lead is harmful, because lead is a cumulative poison. The exact amount of lead which may be taken into the system without producing harm is not definitely known, and may vary in different people; but it is known that the continued use of water containing quantities of lead as small as .05 of a part per 100 000 or about $\frac{1}{33}$ of a grain per gallon, has caused serious injury to the health."

By an examination of the several tables which are given in this report, it will be seen that the water in many cities and towns which is drawn through lead service pipes contains a much larger amount

of lead than .05 parts in 100 000, and it is a fact well established in this report that lead poisoning of quite a serious nature has occurred in this state from the use of water drawn through lead service pipes.

The investigation of the State Board of Health has also shown that a change in the source of supply — that is, furnishing a different water through the same lead pipes — may make the use of water dangerous to health where no danger existed before, on account of a much larger amount of lead now dissolved.

It is found that there are many things which contribute to increase or decrease the amount of lead which a water may take up.

I should like again to quote from this report; we read on page 563 as follows: "A review of results of all experiments indicates strongly that the two active agents in the waters, causing them to take lead into solution, were oxygen and carbonic acid. The purer the water (for instance, distilled water), the more active these agents were upon lead when in this water. The presence of nitrates and ammonia in distilled water, together with free access of air, caused a very violent action upon the lead to take place; but they had much less influence when present in natural waters containing some organic matter."

On page 566 it reads as follows: "A study of this table shows that the clear and practically colorless supplies, which most actively attack lead, are those containing the most carbonic acid and a small or a medium amount of mineral matter, as shown by the determination of hardness." On page 568, we find the following: "Again, it was shown by our experiments that highly colored water would attack lead, if sufficient time and air were allowed for the change of the carbonaceous coloring matter to carbonic acid in the presence of oxygen. This change probably occurs when some highly colored surface waters remain in the service pipes for some hours." The report goes on to say, farther down on the same page: "In —— we have a marked example of a water which, while not acting so violently upon lead that much is taken from the pipes when the water is drawn frequently, still is of such a character that, when allowed to remain for a considerable period of time in the pipes, it takes considerable lead both in solution and suspension from them; that is, a coating of organic and mineral matter forms upon the pipes, carbonic acid is generated, which, together with the oxygen present, attacks the lead, and this deposit is, when the water is drawn quickly after hours of rest, apparently easily detached from the pipe and drawn out, thus increasing the amount of lead in water

drawn after periods of rest above that actually taken into solution by the water during this period of rest."

These quotations show the many causes which make it possible for water to dissolve lead, and should teach us to look with extreme caution to the use of lead for service pipes. It is also quite a serious matter, from a financial standpoint, to invest thousands of dollars in lead pipe, and then find that we have an element of serious danger in our midst which, sooner or later, must be remedied. The health of a community must first be considered; this goes without saying.

Now, in the light of so much conclusive evidence which is within our reach, what position should we take in this matter in constructing and maintaining a system of water works? Is it not wiser and better to eliminate all possible elements of danger from a thing so vital as the water which we must daily take into our bodies? We must bear this fact in mind: that ordinary citizens know little about these things, and trust to those who have charge of the water supplies to furnish them with a good and safe water, and we should not be unmindful of the confidence placed in us. I hope this brief discussion will draw more attention to this very important subject, and that we all shall realize the responsibilities which we have assumed.

Discussion.

Mr. H. W. Clark.* Mr. President, on this subject of lead poisoning, I should like to say just a few words. It is not a new subject at all. The fact that lead would poison the human system has been known for a great many years. Galen, who was a very famous physician in the second century of the Christian era, described lead poisoning very thoroughly, and stated that water would affect lead pipes or lead conduits, and that water taken into the city through them was harmful. Then again, Vitruvius, who was an architect in the time of Cæsar Augustus, forbade the use of lead pipes in connection with water supplies.

Coming down to rather more modern times, however, we find that there have been a good many epidemics of lead poisoning, not only the few referred to in the Report of the State Board of Health of Massachusetts of 1898, but a good many abroad. For instance, there is a well-known case of the city of Dessau, in Saxony, where

* Chemist, Massachusetts State Board of Health.

they had an epidemic of lead poisoning in 1885 or 1886. They got over it, that is, prevented the continuance of the action of the water upon the pipes by hardening the water, adding a certain percentage of carbonate of lime, increasing the hardness about sixty per cent. Then in Sheffield, England, they had a large epidemic of lead poisoning some years ago, and there they afterwards passed the water through filters of limestone and silicates, hardening the water from sixty to one hundred per cent., and thus preventing, more or less, the water from attacking the lead.

Then, in certain places in England they have, for this purpose, passed the water through towers of coke, and afterwards through filters of limestone, with the same effect of hardening the water.

In one or two places they have tried softening the water; that is, recognizing, probably, that it was the carbonic acid that attacked the pipes, they have added milk of lime to absorb the carbonic acid, which has caused a precipitation of some of the sulphates and carbonates in the water; and in this manner, after filtration, the water has been passed into the pipes with some beneficial effect.

Then in one or two places they have tried coating the pipes with sulphide of lead. But in all these various places where they have adopted different methods of changing the character of the water supply to prevent its attacking the lead, I think they have not been particularly successful, except where they have hardened the water, as in Dessau, Sheffield, and Keighley, and there may be one or two other places.

But this is not a new subject, by any means, as I have said, and people will go on using lead pipes right along, because there are many supplies, even in Massachusetts, the water from which does not attack lead seriously. But there are a good many more in connection with which we are pretty sure lead should not be used.

A MEMBER. I would like to ask Mr. Clark if galvanized iron pipe can be used with safety where lead pipes are found dangerous.

MR. CLARK. In such cases the zinc galvanizing of these iron pipes is attacked, of course, or at least as far as our experience has gone, similarly with the lead, until a great deal of it is taken off. There seems to be left for a long period a very thin coating of zinc, and, so far as we know, zinc is not a particularly poisonous element when taken into the system. It may have some effect, but not a great deal.

MR. THOMAS. I would like to ask Mr. Clark if he knows or has

heard of any carbonate or sulphate which can be applied to water which will protect it from the action of lead and yet not harden the water.

Mr. Clark. I don't really know of any that would. I think, perhaps, sodium carbonate would; it is used for softening waters, but I do not see why sodium carbonate should satisfactorily prevent action upon lead. I have made a great many laboratory experiments with various chemicals, and have been successful in preventing action only when the water is hardened.

PROCEEDINGS.

ANNUAL MEETING.

Association Rooms, Tremont Temple,
Boston, June 13, 1900.

President Cook in the chair.

The following members and guests were present: —

Active Members.

Francis E. Appleton, Wm. E. Badger, E. W. Bailey, Lewis M. Bancroft, Joseph E. Beals, James W. Blackmer, 2d; Dexter Brackett, Fred Brooks, George A. P. Buckman, James Burnie, George Cassell, G. L. Chapin, Byron I. Cook, J. W. Crawford, George E. Crowell, D. W. Cole, Francis W. Dean, William T. Dotten, Eben R. Dyer, F. F. Forbes, Wm. E. Foss, H. F. Gibbs, J. F. Gleason, Albert S. Glover, Amos A. Gould, Frederick W. Gow, James W. Graham, Frank E. Hall, Allen Hazen, Horace G. Holden, John L. Howard, Willard Kent, Frank E. Merrill, Leonard Metcalf, Thomas Naylor, J. B. Putnam, Charles E. Riley, W. W. Robertson, Thomas H. Rogers, W. J. Sando, Walter H. Sears, Charles W. Sherman, Sidney Smith, George A. Stacy, Frederic P. Stearns, Wm. F. Sullivan, Joseph G. Tenney, Robert J. Thomas, D. N. Tower, George W. Travis, William W. Wade, Charles K. Walker, George E. Wilde, Frederic I. Winslow, E. T. Wiswall.

Associate Members.

Ashton Valve Co., by C. W. Houghton; Coffin Valve Co., by F. E. Adams and H. L. Weston; Mellen S. Harlow; Lead Lined Iron Pipe Co., by T. E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by J. G. Lufkin; Perrin, Seamans & Co., by Harold L. Bond; Rensselaer Mfg. Co., by Fred S. Bates; Builders' Iron Foundry, by F. N. Connet; Sumner & Goodwin Co., by Frank E. Hall; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by A. S. Otis; Walworth Mfg. Co., by B. F. Polsey; R. D. Wood & Co., by E. F. Krewson; Hersey Mfg. Co., by Albert S. Glover.

Guests.

F. C. Cook, Somerville; Hon. S. P. Tenney, Chairman Water Commissioners, Chelsea, Mass.; Edward M. Shedd, Inspector, Somerville, Mass.; Wm. P. Jones and E. B. Pense, Editor and City Editor *Somerville Journal*, Somerville, Mass.; George E. Borden, Fall River, Mass.; M. J. Dowd, Commissioner, Lowell, Mass.; W. C. Morgan and F. E. Hunter, Beverly, Mass.; S. M. Spencer, Boston, Mass.; C. B. Crowell, Brattleboro, Mass.;

E. F. Knowlton, Commissioner Public Works, Quincy, Mass.; Charles H. Sargent, Newburyport, Mass.; George T. Staples, Dedham, Mass.

The following new members were elected: —

Resident Active. —E. R. Payson, Secretary Portland Water Works Co., Portland, Me.; Henry Souther, Member Board of Water Commissioners, Hartford, Conn.; Norman A. McMillan, Superintendent Billerica Water Works, North Billerica, Mass.

Non-Resident Active. — Myron E. Evans, Civil Engineer, New York City.

Associate. — Sweet & Doyle, Selling Agents The Vincent Valve, Cohoes, N. Y.

On motion it was voted that a committee to nominate candidates for the offices to be filled at the annual election be appointed by the chair. The president stated that he would announce his appointments at a later time. Subsequently the membership of the committee was announced as follows: J. C. Whitney, P. Kieran, Charles K. Walker, D. N. Tower, and F. F. Forbes.

On motion of Mr. Charles W. Sherman, it was voted that the annual meeting adjourn to the third Wednesday in September, at Rutland, Vt.

Adjourned.

The annual "field day" was then observed by an excursion to the works of the Metropolitan Water Works at Spot Pond and Fells Reservoir, and to the reservoirs of the Winchester Water Works.

OBITUARY NOTE.

JOHN C. HASKELL, past president and member of the executive committee of this Association, committed suicide by shooting himself through the heart with a double-barreled shotgun on June 12, 1900.

Mr. Haskell was born in Rochester, Mass., about fifty-five years ago. He had been city engineer of Lynn, and about twelve years ago was elected superintendent of the Lynn Water Works, which position he held until his resignation on May 12. He was elected a member of this Association on Dec. 11, 1889, and has been very prominent in its affairs, having served on many committees, and as president in 1896–1897. He was the author of several papers in the Journal, and frequently took part in the discussions.

He was a member of the Boston Society of Civil Engineers. He was also a Mason and an Odd Fellow. He was unmarried.

WATER WORKS STATISTICS

FOR THE YEARS

1897, 1898 and 1899,

IN FORM ADOPTED BY THE

New England Water Works Association.

COMPILED BY

JOSEPH E. BEALS,

Senior Editor.

1900.

1897.—TABLE 1.—GENERAL AND PUMPING.

Number.	Name of City or Town.	Date of Construction.	By whom Owned.	Source of Supply.	Mode of Supply.	1 Builders of Pumping Machinery.	2.—Description of Coal Used. b Kind.	c Size.	d Brand.	e Price per Ton.	f Per Cent. of Ash.	g Wood. Price per Cord.
1	Atlantic City. N. J.											
2	Attleboro, Mass.	1873	Town.	Well near Seven Mile River.	Pumping to Standpipe.	Blake, Deane.	Bituminous.		Georges Creek.	$4 25		
3	Billerica, Mass.											
4	Boston, Mass. Cochituate	1848	City.	Lake Cochituate, Sudbury River, and Mystic Lake.	65% Gravity Works.	Holly, Quintard, Worthington,	Bituminous.	Broken.		3 47 to 3 57	9.2	
	Mystic	1864			35% Pumping Works.	Blake.	Bituminous.	Broken.		3 18	11.4	
5	Brockton, Mass.	1880	City.	Storage Reservoir, Salisbury Brook.	Pumping to Standpipe.	Worthington, Holly.						
6	Burlington, Vt.	1867–68	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.		Clearfield.	3 85		
7	Concord, N. H.											
8	Fall River, Mass.	1874	City.	Watuppa Lake.	Pumping to Standpipe and Tank.	Worthington, Davidson.			Georges Creek.			
9	Fitchburg, Mass.		City.	Storage Reservoir and Pond.	Gravity.							
10	Holyoke, Mass.	1873	City.	Lakes, Streams, and Reservoir.	Gravity.							
11	Keene, N. H.											
12	Lowell, Mass.	1870–96		Driven Wells and Filter Gallery.	Pumping to Reservoir and Direct.	Morris, Deane, Worthington, Knowles.	Bituminous.	Broken.	Cumberland.	3 94		
13	Lynn, Mass.	1870–97	City.	Storage Reservoir and Saugus River.	Pumping.	Morris, Loretz.			Georges Creek.	4 14		
14	Middleboro, Mass.	1885	F. Dist.	Well.	Pumping to Standpipe.	Deane.	Bituminous.		Georges Creek & Pocahontas.	4 50 3 90		

15	New Bedford, Mass.	1866–69	City.	Storage Reservoir and Acushnet River.	Gravity and Pumping.	McAlpine, Worthington.	Bituminous.		Pocahontas.	$3 55 3 00	7	$4 00
16	New London, Conn.	1872	City.	Lake Konomoc.								
17	Newton, Mass. . . .	1876	City.	FilterGalleryfed by Springs and Driven Wells.	Pumping to Reservoir.	Blake, Worthington.	Bituminous.	Broken.	Georges Creek & Cumberland.	3 66	6	6 00
18	Oberlin, Ohio	1887	Village.	EastBranchVermillion River.	Pumping.	Deane.	Bituminous.			2 24		
19	Plymouth, Mass. . .	1855	Town.	Great and Little South and Lout Ponds.	Gravity and Pumping.	Worthington.	Bituminous.			4 50		
20	Providence, R. I. . .	1870–76	City.	Pawtuxet River.	Gravity and Pumping.	Corliss.	Anthracite.	Pea.	Beaver Meadow.	4 48		
						Cornish, Worthington.	Anthracite and Bituminous.	Pea.	Beaver Meadow.	4 18		4 50
						Nagle.	Anthracite.	Egg.	Wilkesbarre.	5 32		5 00
						Holly.	Anthracite.	Egg.	Wilkesbarre.	5 31		5 00
21	Reading, Mass. . . .	1890–91	Town.	Filter Gallery.	Pumping to Standpipe.	Blake.	Bituminous.		Georges Creek.	4 80		
22	Springfield, Mass. .	1864–94	City.	Impounding Reservoirs fed by Springs, Streams, and SurfaceWater.	Gravity.							
23	Taunton, Mass. . . .	1876	City.	Elder's Pond, Lakeville.	Gravity and Pumping.	Holly and Allis.	Bituminous.		Cumberland.	3 85 3 60	8.28 0.43	
24	Troy, N. Y.	1833–98	City.	Storage Reservoir and Hudson River.	Gravity and Pumping.	Holly.	Anthracite.	Buckwheat.		2 69 2 54	17.81	5 00
25	Waltham. Mass. . .	1872–73	City.	Filter Basin, near Charles River.	Pumping.	Worthington.	Bituminous.		Georges Creek & Pocahontas.	4 10	10.	
26	Wellesley, Mass. . .											
27	Whitman, Mass. . .	1883–84	Town.	Well.	Pumping.	Blake, Worthington.						
28	Woonsocket, R. I. .	1884	City.	Crook Falls Brook.	Pumping to Tanks.	Worthington, Deane.	Bituminous.		Pocahontas.	4 07	6.4	3 00

	3	4	5	6	7	8	9	10	11	12	13	14
Number.	Coal Consumed for the Year. Lbs.	Lbs. of Wood ÷ 3.	Total Fuel Consumed for the Year. Lbs.	Total Pumpage for the Year in Gallons.	Average Static Head against which Pumps Work. Feet.	Average Dynamic Head against which Pumps Work. Feet.	Number of Gallons per Pound of Coal.	Duty in Foot-pounds per 100 Pounds of Coal. No Deductions.	Cost per Million Gallons Pumped into Reservoir, figured on Pumping Station Expenses.	Cost per Million Gallons raised 1 foot high, figured on Pumping Station Expenses.	Cost per Million Gallons Pumped into Reservoir, figured on Total Maintenance.	Cost per Million Gallons raised 1 foot high, figured on Total Maintenance.
1	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
2	483 536	1 000	484 536	125 716 250	160	175 Blake 188 Deane	260	41 000 000	$13 18	$0 0732	$151 00	$0 842
3	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
4	5 157 939 7 421 103	1 000	. . .	5 250 063 975 4 572 225 608	. . . .	. . . . . .	1 017 9 616 1	. . . . . .	5 706 6 122	. . . . . .	. . . . . .	. . . . . .
5	401 955	. .	. . .	391 977 403	. .	43	975 17	. . .	7 17	0 166	104 60	2 43
6	. . .	. .	. . .	282 550 525	289	316	. .	. . .	28 73	0 09	176 46	0 558
7	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
8	. . .	. .	. . .	1 339 418 534	. .	185 42	331 83	. . .	10 26	. . .	105 66	. . .
9	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
10	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. .	. . .	. . .	. . .
11	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
12	2 367 459	2 400	2 369 859	1 352 724 180	156 72	162 66	571	77 434 333	8 02	0 0493	. . .	. . .
13	567 300 2 285 150	900	567 300 2 286 050	271 907 330 1 423 543 150	. . . .	172 16 166 72	479 628 80	75 091 203 86 867 596	6 61	0 0394	81 37	0 4855
14	442 480	. .	442 480	71 489 000	180	201	161 56	27 061 836	32 84	0 1636	96 14	0 4775
15	2 891 050	437	2 891 487	2 066 830 472	125 2 131 6 124 7	134 5 133 23 127 04	672 491 831	75 393 352 54 526 055 88 065 751	5 82	0 0443	46 28	0 3523
16	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
17	1 544 400	8 000	1 552 400	659 284 000	234	253	424	110 000 000	12 28	0 05	168 14	0 66
18	290 000	. .	. . .	24 584 700	80	80	84 8	5 656 000	49 00	0 61	190 80	2 38
19	240 100	. .	. . .	108 868 320	65	66	482 57	26 562 583	15 08	0 22	107 26	1 62
20	35 500 4 913 750 40 501 923 090	. . 500 187 2 203	35 500 4 914 250 40 688 925 293	. . . 3 412 572 606 20 599 984 511 964 360	. . 170 3 112 112	. . . 175 88 116 66 139	. . 694 500 555	. . . 101 860 800 49 259 300 61 141 800	Low Serv. 4 62 High Serv. 16 25	0 0263 0 1105	. . . . . .	. . . . . .
21	449 830	. .	449 830	52 341 850	219	240	116	. . .	83 37	0 347	282 40	1 17
22	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
23	718 700 354 100	. . . .	718 700 354 100	454 765 940	. .	62 42	632 76	32 940 479	11 22	0 1797	108 91	1 74
24	11 476 193	. .	. . .	2 818 753 723	231	242	245 62	49 572 487	12 34	0 051	30 70	. . .
25	2 005 320	. .	. . .	562 307 588	164	180	284	44 571 950	13 88	0 077	71 05	0 395
26	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
27	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
28	980 225	193	980 418	269 989 707	238	239	275 4	55 624 546	14 41	0 0603	111 16	0 46

1897. — TABLE 11. — FINANCIAL. — MAINTENANCE.

Number.	Name of City or Town.	Receipts from Consumers. A Rates. Domestic.	B Rates. Manufacturing.	C Net Receipts for Water.	D Miscellaneous Receipts.	E Total Receipts.
1	Atlantic City, N. J.	. . .	. . .	. . .	. . .	. . .
2	Attleboro, Mass.	. . .	. . .	. . .	. . .	$ 16 446 69
3	Billerica, Mass.	. . .	. . .	. . .	. . .	. . .
4	Boston, Mass. { Cochituate	. . .	. . .	. . .	. . .	. . .
	Boston, Mass. { Mystic	. . .	. . .	. . .	. . .	. . .
5	Brockton, Mass.	[1] $ 44 043 87	[2] $ 8 785 56	$ 52 829 43	$ 178 20	53 007 63
6	Burlington, Vt.	35 151 38	4 189 65	39 341 03	2 115 86	41 456 89
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	[1] 134 679 84	[2] 5 606 66	140 286 50	7 513 38	147 799 88
9	Fitchburg, Mass.	53 185 07	13 242 27	66 427 31	. . .	. . .
10	Holyoke, Mass.	[1] 12 219 85	[2] 64 581 98	76 801 83	. . .	76 801 83
11	Keene, N. H.	. . .	. . .	. . .	. . .	. . .
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	122 761 67	50 258 34	173 020 01	8 742 93	181 762 94
14	Middleboro, Mass.	7 732 98	2 912 59	10 285 57	115 98	10 401 55
15	New Bedford, Mass.	92 291 78	7 376 33	99 668 11	98 90	99 767 01
16	New London, Conn.	. . .	. . .	. . .	. . .	42 583 23
17	Newton, Mass.	[1] 83 052 35	[2] 22 394 37	105 446 72	. . .	. . .
18	Oberlin, Ohio	3 584 21	380 00	3 964 21	644 96	4 609 17
19	Plymouth, Mass.	18 239 41	1 286 50	19 525 91	540 19	20 066 10
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	8 047 46	95 56	8 143 02	182 69	8 325 71
22	Springfield, Mass.	[1] 56 806 93	[2] 130 306 73	187 113 66	. . .	. . .
23	Taunton, Mass.	36 542 99	11 421 97	47 964 96	353 85	48 318 81
24	Troy, N. Y.	[1] 21 115 38	[2] 72 553 37	93 668 75	5 656 39	99 325 14
25	Waltham, Mass.	52 582 19	6 213 95	58 796 14	3 808 74	62 604 88
26	Wellesley, Mass.	. . .	. . .	. . .	. . .	. . .
27	Whitman, Mass.	. . .	. . .	. . .	. . .	. . .
28	Woonsocket, R. I.	34 261 28	4 922 13	39 183 41	105 71	39 289 12

[1] Meter Rates. [2] Faucet Rates.

1897.—TABLE II., *Continued.*—FINANCIAL.—MAINTENANCE.

Number.	Receipts from Public Funds.							Expenditures.				
	F	G	H	I	J	Total from Public Fund.	K	AA	BB	CC	DD	EE
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.		Gross Receipts.	Management and Repairs.	Interest on Bonds.	Total Maintenance for the Year.	Balance.	Total.
1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2	. . .	. . .	. . .	. . .	$ 7 166 67	$ 7 166 67	$ 23 166 67	$ 7 353 45	$ 11 600 00	$ 18 953 45	$ 4 659 91	$ 23 613 36
3	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5	$ 3 000 00	. . .	$1 000 00	. . .	. . .	4 000 00	57 007 63	10 354 88	30 647 50	41 002 30	[3] 16 005 25	57 007 63
6	3 480 00	$ 250 00	1 778 49	$ 333 80	2 561 44	8 403 73	49 860 62	39 210 62	10 650 00	49 860 62	. . .	49 860 62
7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	. . .	. . .	. . .	. . .	. . .	7 000 00	[2] 594 20 155 394 08	51 915 46	103 155 00	155 070 46	323 62	155 394 08
9	. . .	. . .	. . .	. . .				12 779 50	. . .			
10	3 000 00	. . .	. . .	439 20	. . .	. . .	. . .	16 147 95	25 000 00	. . .	. . .	. . .
11	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
13	. . .	. . .	. . .	. . .	. . .	. . .	181 762 94	64 018 31	73 846 24	137 864 55	[3] 43 898 39	181 762 94
14	. . .	. . .	. . .	. . .	. . .	2 000 00	[2] 16 90 12 401 55	4 252 92	2 620 00	6 872 92	[3] 2 500 00 [4] 2 773 00 272 20	12 418 45
15	. . .	. . .	. . .	. . .	70 000 00	70 000 00	169 767 01	27 652 73	68 000 00	95 652 73	[3] 44 000 00 [4] 30 114 28	169 767 01
16	10 600 00	150 00	3 600 00	225 00	. . .	13 575 00	57 158 23	6 192 23	24 540 00	30 732 23	[4] 26 426 00	57 158 23
17	. . .	. . .	. . .	. . .	. . .	. . .	. . .	18 154 93	92 700 00	. . .	. . .	. . .
18	. . .	. . .	. . .	. . .	2 700 00	2 700 00	7 309 17	2 092 70	2 600 00	4 692 70	[4] 2 616 47	7 309 17
19	. . .	. . .	. . .	. . .	. . .	. . .	20 066 10	7 718 17	3 860 00	11 578 17	[4] 3 347 93 5 140 00	20 066 10
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
21	3 300 00	. . .	. . .	. . .	[1] 515 77 2 570 00	6 415 77	14 741 48	6 541 48	8 200 00	14 741 48	. . .	14 741 48
22	17 840 00	1 640 20	5 015 54	4 481 25	25 000 00	53 976 99	. . .	21 294 11	94 250 00	. . .	. . .	. . .
23	2 500 00	1 756 00	800 00	545 12	817 56	6 418 68	54 737 49	21 131 65	28 408 00	49 539 65	5 197 83	54 737 49
24	. . .	. . .	. . .	. . .	. . .	. . .	99 325 14	61 112 69	10 897 50	72 010 19	[3] 19 137 50 [4] 8 177 45	99 325 14
25	. . .	. . .	. . .	. . .	. . .	. . .	62 604 88	23 113 79	16 840 00	39 953 79	[3] 21 500 00 1 151 09	62 604 88
26	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
27	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
28	15 212 50	1 612 26	1 501 18	1 361 49	11 500 00	31 187 43	70 476 55	11 597 35	19 414 74	31 012 09	39 464 46	70 476 55

[1] From Construction. [2] Balance previous year. [3] To Sinking Fund. [4] To Construction Account.

1897.—TABLE II., *Continued.*—FINANCIAL.—CONSTRUCTION AND MISCELLANEOUS.

Number.	Name of City or Town.	Receipts.				
		R	S	T	U	V
		Balance from Previous Year.	Bonds Issued.	Appropriations from Tax Levy.	Other Sources.	Total.
1	Atlantic City, N. J.	. . .	. . .	. . .	. . .	. . .
2	Attleboro, Mass.	$ 5 720 98	$11 025 00	. . .	$ 67 00	$16 812 98
3	Billerica, Mass.	. . .	. . .	. . .	. . .	. . .
4	Boston, Mass. { Cochituate	. . .	. . .	. . .	. . .	. . .
	Boston, Mass. { Mystic	. . .	. . .	. . .	. . .	. . .
5	Brockton, Mass.	11 149 82	40 000 00	. . .	{ 4 721 67 5 155 98 }	61 027 47
6	Burlington, Vt.	. . .	. . .	$ 2 250 00	. . .	2 250 00
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	. . .	. . .	. . .	. . .	. . .
9	Fitchburg, Mass.	. . .	. . .	. . .	7 356 76	. . .
10	Holyoke, Mass.	. . .	. . .	. . .	. . .	. . .
11	Keene, N. H.	. . .	. . .	. . .	. . .	. . .
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	20 590 35	25 000 00	. . .	2 869 59	48 459 94
14	Middleboro, Mass.	[1]2 773 33	. . .	. . .	517 65	3 290 98
15	New Bedford, Mass.	{ 37 822 17 [1]30 114 28 }	. . .	. . .	10 453 64	78 390 09
16	New London, Conn.	{ 62 743 36 [1]26 426 00 }	. . .	. . .	. . .	89 169 36
17	Newton, Mass.	. . .	61 167 48	. . .	14 622 18	75 789 66
18	Oberlin, Ohio	55 15	. . .	. . .	3 060 72	3 115 87
19	Plymouth, Mass.	{ [1]3 347 93 3 253 87 }	. . .	. . .	275 00	6 876 80
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	426 36	26 941 15	1 000 00	726 30	29 093 81
22	Springfield, Mass.	{ 427 27 [1]26 857 47 }	. . .	. . .	. . .	27 284 74
23	Taunton, Mass.	478 83	20 000 00	. . .	3 788 31	24 267 14
24	Troy, N. Y.	{ [1]8 177 45 2 308 90 }	. . .	. . .	. . .	10 486 35
25	Waltham, Mass.	1 674 45	30 000 00	. . .	1 738 95	33 413 40
26	Wellesley, Mass.	. . .	. . .	. . .	. . .	. . .
27	Whitman, Mass.	. . .	. . .	. . .	. . .	. . .
28	Woonsocket, R. I.	. . .	. . .	14 376 84	2 202 13	16 578 97

[1] From Maintenance Account.

1897.—TABLE II., *Continued.*—FINANCIAL.—CONSTRUCTION AND MISCELLANEOUS.

Number.	FF. Expenditures. Extensions. Mains.	GG. Expenditures. Extensions. Services.	HH. Expenditures. Special.	II. Expenditures. Total for Year.	JJ. Expenditures. Balance.	KK. Expenditures. Total.	W. Miscellaneous. Net Cost of Works to Date.	X. Miscellaneous. Bonded Debt to Date.	Y. Miscellaneous. Value of Sinking Fund to Date.	Z. Miscellaneous. Rate of Interest, Per Cent.
1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2	. . .	. . .	. . .	$14 034 08	$ 2 778 90	$16 812 98	$ 323 558 97	$ 265 000 00	$ 38 606 78	. . .
3	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
4	. . .	. . .	. . .	. . .	. . .	. . .	26 831 753 14	17 911 273 98	9 852 760 01	. . .
5	$38 624 16	. . .	$ 8 638 31	47 262 47	13 765 00	61 027 47	844 463 04	760 000 00	235 000 00	4
6	1 775 55	$ 474 45	. . .	2 250 00	. . .	2 250 00	459 628 09	265 000 00	167 145 95	4
7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	. . .	. . .	. . .	. . .	. . .	. . .	2 454 819 84	1 925 000 00	503 747 45	5.3
9	1 250 08	11 354 07	2 126 90	14 731 05	. . .	. . .	531 872 43	736 000 00	204 127 57	4.25
10	2 820 03	2 453 07	. . .	. . .	. . .	. . .	1 011 558 62	500 000 00	276 779 65	. . .
11	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
13	7 599 33	5 425 24	24 689 67	37 714 24	10 745 70	48 459 94	2 363 676 88	1 800 300 00	411 349 10	3.5 to 5
14	2 232 02	1 058 96	. . .	3 290 98	. . .	3 290 98	111 159 23	63 500 00	2 802 18	4
15	27 306 56	10 957 82	. . .	38 264 38	40 125 71	78 390 09	1 740 650 44	580 000 00	13 662 41	5.51
16	9 359 14	1 176 81	21 319 97	31 855 92	57 313 44	89 169 36	629 712 57	426 000 00	. . .	7 and 4
17	. . .	. . .	. . .	75 789 66	. . .	75 789 66	2 013 199 99	2 000 000 00	675 000 00	4.7
18	1 458 76	573 49	1 083 62	3 115 87	. . .	3 115 87	79 589 76	55 000 00	520 50	4.5 to 5.75
19	2 196 56	987 46	910 77	4 094 79	2 782 01	6 876 80	257 269 74	92 880 00	. . .	4
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
21	11 286 95	1 752 68	4 098 98	17 138 61	{ [1]515 77 11 439 43 }	29 093 81	231 587 93	215 000 00	. . .	4
22	22 349 41	. . .	4 508 06	26 857 47	427 27	27 284 74	2 066 236 58	1 575 000 00	280 496 97	5.92
23	6 808 15	6 836 60	9 402 12	23 046 87	1 220 27	24 267 14	1 175 308 73	705 200 00	80 041 65	4
24	2 827 49	. . .	1 013 70	3 841 19	6 645 16	10 486 35	1 281 930 20	273 500 00	51 156 25	4
25	. . .	. . .	. . .	13 652 00	19 761 40	33 413 40	570 977 55	448 000 00	73 440 15	4
26	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
27	. . .	. . .	. . .	. . .	. . .	. . .	124 225 34	100 000 00	. . .	4
28	14 376 84	. . .	. . .	. . .	. . .	. . .	471 780 98	. . .	. . .	. . .

[1] To Maintenance.

1897.—TABLE III.—CONSUMPTION.

Number.	Name of City or Town.	1. Estimated Population. Total at Date.	2. Estimated Population. On Line of Pipe.	3. Estimated Population. Supplied at Date.	4. Total Gallons Consumed for the Year.	5. Quantity Used through Domestic Meters. Gallons.	6. Quantity Used through Manufacturing Meters. Gallons.	Percentage of Total Consumption Metered.	7. Average Daily Consumption. Gallons.	8. Gallons per Day. Each Inhabitant.	9. Gallons per Day. Each Consumer.	10. Gallons per Day. Each Tap.
1	Atlantic City, N. J.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
2	Attleboro, Mass.	8 700	7 200	6 700	125 716 250	. . .	. . .	. .	352 086	40 4	52 5	. .
3	Billerica, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
4	Boston, Mass. { Cochituate	491 100	. .	488 100	21 121 552 400	4 911 650 000		23 3	57 867 300	117 8	118 5	. .
	Boston, Mass. { Mystic	142 600	. .	141 600	4 569 393 100	826 417 500		18 9	12 518 900	87 8	88 4	. .
5	Brockton, Mass.	35 000	33 000	31 500	391 977 403	110 845 545	52 537 170	. .	1 073 910	30 68	34 09	222 38
6	Burlington, Vt.	17 700	17 300	17 100	282 550 525	104 301 121	21 761 250	44 6	774 111	44	45	247
7	Concord, N. H.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
8	Fall River, Mass.	101 106	. .	97 500	1 339 418 534	. . .	. . .	. .	3 669 640	36 29	37 64	. .
9	Fitchburg, Mass.	29 000	25 000	21 000	933 000 000	81 636 000	275 000 000	. .	. . .	88	121	613
10	Holyoke, Mass.	44 835	44 335	43 835	1 375 000 000	211 322 000		. .	3 769 093	85 33	87 33	1 125
11	Keene, N. H.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
12	Lowell, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
13	Lynn, Mass.	68 300	. .	66 000	1 694 258 389	270 236 000		. .	4 641 804	. .	70 16	. .
14	Middleboro, Mass.	{ Town, 7 000 { F. Dist. 4 200	4 000	3 800	71 489 000	. . .	. . .	. .	195 860	46 6	51 5	262
15	New Bedford, Mass.	60 000	51 000	50 000	2 071 702 478	61 828 072	280 223 040	16 5	5 675 897	95	113	641
16	New London, Conn.	15 500	15 000	14 500	460 269 788	. . .	. . .	. .	1 261 013	81	87	449
17	Newton, Mass.	30 000	29 600	29 400	658 300 000	278 000 000	46 000 000	. .	1 803 500	60 1	61 3	274
18	Oberlin, Ohio	4 600	3 500	2 000	24 584 700	6 000 000	1 900 000	33	67 200	14 6	33 6	143
19	Plymouth, Mass.	8 000	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
20	Providence, R. I.	166 000	. .	. .	3 151 799 626	. . .	. . .	. .	8 635 067	52	. .	432
21	Reading, Mass.	4 750	4 160	3 650	52 341 850	6 523 493	894 448	. .	143 065	30 12	39 17	161 2
22	Springfield, Mass.	56 689	50 000	44 000	1 825 000 000	358 841 156		19 66	5 000 000	88	113	573
23	Taunton, Mass.	27 693	26 900	26 801	454 765 740	80 889 135	120 481 185	. .	1 243 194	45 8	46	304
24	Troy, N. Y.	65 000	60 000	58 000	3 660 538 723	389 929 756		. .	10 028 873	154	172	1 423
25	Waltham, Mass.	21 900	21 300	20 800	562 307 588	31 931 962		. .	1 540 569	70	74	492
26	Wellesley, Mass.	. .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
27	Whitman, Mass.	6 000	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
28	Woonsocket, R. I.	28 500	26 500	26 000	271 236 620	212 805 403		. .	742 841	26	28	380

1897.—TABLE IV.—DISTRIBUTION.—MAIN PIPES.

Number.	Name of City or Town.	1. Kind of Pipe.	2. Size of Distribution Pipe in Inches.	3. Length Extended During the Year in Feet.	4. Length Discontinued During the Year in Feet.	5. Total Length in Use. Miles.	6. Cost of Repairs per Mile.	7. Number of Leaks for Year.	8. Length of Pipe Less than 4 in. Diam. Miles.	9. Hydrants. Number Added.	10. Hydrants. Total in Use.	11. Gates. Number Added.	12. Gates. Total in Use.	13. Gates. Number less than 4 Inch.	14. Gates. Number Blow-off Gates.	15. Range of Pressure on Mains at Center for Day and Night. Pounds.
1	Atlantic City, N. J.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	Attleboro, Mass.	C. I. & C. L.	4 to 16	1 273	...	29 82	...	13 00	...	2	236	...	...	...	...	50 to 62
3	Billerica, Mass.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	Boston, Mass. Cochituate	C. I.	4 to 48	102 960	...	627 1	...	...	2 2	178	6 547	323	7 410	...	...	...
	Boston, Mass. Mystic	C. I., W. I. & Cem.	3 to 36	13 728	...	187 2	...	...	4 00	79	1 718	128	2 519	...	...	...
5	Brockton, Mass.	W. I., C. L. & C. I.	6 to 30	23 440	0	61 28	$ 0 52	[1]0 19	...	46	565	54	630	...	18	47 to 56
6	Burlington, Vt.	C. L., C. I. & W. I.	4 to 30	2 094	6 918	36 00	8 22	[1]0 42	3 00	15	205	28	541	62	12	70 to 85
7	Concord, N. H.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	Fall River, Mass.	C. I.	6 to 24	...	...	62 3	...	...	...	55	882	50	861	...	...	80
9	Fitchburg, Mass.	W. I., C. L. & C. I.	2 to 30	7 020	...	63 42	3 57	36 00	1 33	14	439	25	519	...	...	155 to 160 75 to 80
10	Holyoke, Mass.	W. I. & C. I.	½ to 20	3 266	0	63 00	4 20	4 00	5 6	5	426	15	545	1	17	45 to 65 80 to 100
11	Keene, N. H.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	Lowell, Mass.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	Lynn, Mass.	W. I., C. L. & C. I.	2 to 20	2 125	...	109 24	...	146 00	...	1	171	6	942	...	...	50 to 65
14	Middleboro, Mass.	C. I.	4 to 12	2 797	...	15 95	...	0	...	4	112	6	154	...	5	45 to 60
15	New Bedford, Mass.	W. I. C. L. & C. I.	4 to 36	27 566	8 844	87 51	9 17	7 00	1 2	23	693	46	974	72	91	28 to 39
16	New London, Conn.	W. I. C. L. & C. I.	4 to 20	1 686	0	45 00	18 29	[1]0 7	3 00	5	212	17	259	...	29	45 to 50
17	Newton, Mass.	C. I.	4 to 20	27 026	0	130 8	12 15	15 00	2 9	44	879	51	735	46	343	84
18	Oberlin, Ohio	C. I.	4 to 12	1 730	0	8 1	0	0	0 33	2	74	3	48	2	2	27 to 32
19	Plymouth, Mass.	W. I. & C. L.	2 to 20	2 922	0	36 9	9 38	[1]1 00	10 5	2	120	6	325	129	22	...
20	Providence, R. I.	Low Serv., C. I.	6 to 36	38 270	499	310 35	...	...	0	33	1 787	92	3 216	...	32	64 to 73
		High Serv. Fire, C. I.	12, 16, 24	...	...	5 57	...	...	...	...	89	...	31	...	4	114
21	Reading, Mass.	C. I.	4 to 12	14 093	0	23 08	0	0	0	10	121	13	208	0	14	68 to 78
22	Springfield, Mass.	W. I., W. I. C. L. & C. I.	¾ to 36	44 902	8 434	134 71	7 57	85 00	7 3	51	892	138	1 683	297	86	100 to 120 30 to 35
23	Taunton, Mass.	C. I.	4 to 30	11 300	0	73 7	40 63	5 00	1 25	13	737	12	504	11	52	45 to 50
24	Troy, N. Y.	C. I.	4 to 30	3 603	16	58 81	5 74	20 00	0 56	7	762	8	1 272	...	37	9 to 107
25	Waltham, Mass.	C. I., W. I. & C. L.	2 to 24	2 287	...	49 00	2 10	[1]0 4	...	15	306	10	633	...	...	58
26	Wellesley, Mass.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27	Whitman, Mass.	C. L. & C. I.	...	...	...	17 00	...	...	...	...	148	...	...	...	...	65
28	Woonsocket, R. I.	C. I.	4 to 20	4 320	...	43 47	2 17	0	0	9	523	10	426	...	16	50 to 120

[1] Per mile.

Number.	Name of City or Town.	16 Service Pipe. Kind.	17 Service Pipe. Size. Inches.	18 Service Pipe. Extended. Feet.	19 Service Pipe. Discontinued. Feet.	20 Service Pipe. Total in Use. Miles.	21 Service Taps. Added.	22 Service Taps. Total in Use.	23 Average Length of Services.	24 Average Cost of Services.	25 Meters. Added.	26a Meters. Now in Use. Domestic.	26b Meters. Now in Use. Manufacturing.	27 Motors and Elevators. Added.	28 Motors and Elevators. Total in Use.
1	Atlantic City, N. J.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. .	.	.	. .
2	Attleboro, Mass.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	67	740		0	0
3	Billerica, Mass.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. .	.	.	. .
4	Boston, Mass. Cochituate	Lead.	⅝ to 6	56 075	. .	. .	2 465	75 785	. .	. .	.	4 436		.	625
	Boston, Mass. Mystic	Lead, W. I.	½ to 4	23 369	. .	. .	906	25 848	. .	. .	.	501		.	21
5	Brockton, Mass.	W. I., L. L., C. L., C. I.	¾ to 6	12 168	503	26 39	226	4 829	45 74	. .	319	3 701		.	. .
6	Burlington, Vt.	G. I., Lead.	½ to 6	2 177	70	17 00	70	3 137	30 00	7 28	249	1 752	49	3	33
7	Concord, N. H.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. .	.	.	. .
8	Fall River, Mass.	Lead.	½ to 2	. .	. .	. .	317	6 422	. .	. .	347	5 954		.	. .
9	Fitchburg, Mass.	W. I., C. L., C. I.	¾ to 8	7 194	. .	45 42	118	4 169	61	21 35	160	1 841	190	10	80
10	Holyoke, Mass.	C., R. L., Enam., C. I., Lead.	⅝ to 4	1 980	4	13 04	99	3 444	20	14 56	4	200		1	45
11	Keene, N. H.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. .	.	.	. .
12	Lowell, Mass.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. .	.	.	. .
13	Lynn, Mass.	L., C. L., Adam., G. I., L. L.	¾ to 10	9 151	870	. .	Saugus 54	802	51 4	.	307	1 868		.	. .
							Lynn 185	11 374	42 9					.	. .
14	Middleboro, Mass.	C. L., Lead.	¾ to 3	1 267	. .	8 28	26	747	50 0	. .	19	292		0	6
15	New Bedford, Mass.	Lead, C. I.	½ to 10	18 803	552	56 52	413	8 860	44 0	18 09	255	556	62	29	110
16	New London, Conn.	W. I. C. L., G., C. I., L.	½ to 4	1 532	0	10 3	70	2 811	22 0	11 91	10	197		1	16
17	Newton, Mass.	L., W. I., C. I.	½ to 6	18 250	4 000	73 8	297	6 573	59 0	23 00	426	5 100	25	0	17
18	Oberlin, Ohio	G. I., Lead.	¾ to 2	. .	. .	. .	28	471	25 0	8 00	37	169	5	0	0
19	Plymouth, Mass.	L., C. L.	½ to 1	452	. .	5 65	51	1 711	17 67	4 50	.	. .	.	0	1
20	Providence, R. I.	L., C. I.	½ to 10	. .	. .	. .	698	19 993	. .	. .	893	15 679		6	138
21	Reading, Mass.	G. I., C. L., L. L., C. I.	¾ to 6	5 344	481	11 19	75	887	71 12	23 36	51	186		0	3
22	Springfield, Mass.	W. I., C. I.	½ to 6	. .	. .	. .	423	8 721	. .	. .	197	2 496		2	174
23	Taunton, Mass.	C. L. W. I., T. L. W. I.	¾ to 3	7 075	6 015	39 67	145	4 090	. .	21 49	95	1 386	150	0	14
24	Troy, N. Y.	L., C. I.	¾ to 6	. .	. .	1 33	194	. .	35 0	25 00	15	278		.	. .
25	Waltham, Mass.	C. I., W. I. C. L.	¾ to 8	4 113	42	35 4	44	3 130	93 0	25 18	0	75		0	6
26	Wellesley, Mass.	. . .	. .	. .	. .	. .	. . .	. .	. .	. .	.	. .	.	.	. .
27	Whitman, Mass.	. . .	. .	. .	. .	. .	. . .	903	. .	. .	.	. .	.	.	. .
28	Woonsocket, R. I.	L., I.	⅝ to 6	1 083	. .	5 7	80	1 952	12 8	11 71	86	1 637	48	3	12

1898.—TABLE I.—GENERAL AND PUMPING.

Number.	Name of City or Town.	Date of Construction.	By whom Owned.	Source of Supply.	Mode of Supply.	1 Builders of Pumping Machinery.	2.—Description of Coal Used. b Kind.	c Size.	d Brand.	e Price per Ton.	f Per Cent. of Ash.	g Wood. Price per Cord.
1	Atlantic City, N. J.	1882, 1888	City.	Driven Wells and Absecon Creek. Five Artes'n Wells	Pumping to Standpipe and Direct.	Worthington, Gordon-Maxwell, Smith-Vaile.	Bituminous. Anthracite.	Run of Mine. Pea.		$2 94, 2 74, 3 27, 3 52	5, 9.85	
2	Attleboro, Mass. . .	1873	Town.	Circular Well near Seven Mile River.	Pumping to Standpipe.	Blake, Deane.	Bituminous.		Georges Creek.	4 15		
3	Billerica, Mass. . . .											
4	Boston, Mass. . . .											
5	Brockton, Mass. . .	1880	City.	Storage Reservoir on Salisbury Brook.	Pumping to Standpipe.	Worthington, Holly.						
6	Burlington, Vt. . . .	1867–68	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.		Reynoldsv'll	2 67		
7	Concord, N. H. . . .	1872	City.	Penacook Lake.	Gravity and Pumping.		Bituminous.		Pocahontas.			
8	Fall River, Mass. . .	1874	City.	Watuppa Lake.	Pumping to Standpipe.	Worthington, Deane.	Bituminous.		Georges Creek.			
9	Fitchburg, Mass. . .		City.	Storage Reservoirs.	Gravity.							
10	Holyoke, Mass. . . .	1873	City.	Natural Lakes, Mountain Streams, and Storage Reservoirs.	Gravity.							
11	Keene, N. H.											
12	Lowell, Mass.	1870–96	City.	Driven Wells and Filter Gallery.	Pumping to Reservoir and Direct.	Morris, Worthington, Deane, Knowles.	Bituminous.	Broken.	Cumberland.	3 42		
13	Lynn, Mass.	1870–98	City.	Storage Basins.	Pumping to Reservoir.	Leavitt, Loretz.			Georges Creek.	3 64		

14	Middleboro, Mass. .	1885	F. Dist.	Well.	Pumping to Standpipe and Direct.	Deane.	Bituminous.		Georges Creek & Pocahontas.	$3 90 3 85		
15	New Bedford, Mass.	1866–69	City.	Storage Reservoir.	Gravity and Pumping.	McAlpine, Worthington.	Bituminous.		Pocahontas.	3 00 3 50	7	$4 00
16	New London, Conn.	1872	City.	Lake Konomoc.								
17	Newton, Mass. . . .	1876	City.	FilterGalleryfed by Springs and Driven Wells.	Pumping to Reservoir.	Blake, Worthington.	Bituminous.	Broken.	Georges Creek.	3 50	7	6 00
18	Oberlin, Ohio	1887	Village.	EastBranchVermillion River.	Pumping.	Deane.	Bituminous.	Run of Mine.	Pocahontas.	3 36		
19	Plymouth, Mass. . .	1855	Town.	Great and Little South and Lout Ponds.	Gravity and Pumping.	Worthington.	Bituminous.			4 50		
20	Providence, R. I. . .	1870–76	City.	Pawtuxet River.	Gravity and Pumping.	Cornish, Worthington.	W. Anthracite and Bituminous.	Pea.	Beaver Meadow, Georges Creek.	3 91		4 50
						Corliss, Nagle and Holly.	H. Anthracite	Egg.	Wilkesbarre, Reading.	5 32		5 00
21	Reading, Mass. . . .	1890–91	Town.	Filter Gallery.	Pumping to Standpipe.	Blake.	Bituminous.		Georges Creek.	4 70		
22	Springfield, Mass. .	1864–94	City.	Impounding Reservoirs.	Gravity.							
23	Taunton, Mass. . . .	1876	City.	Elder's Pond, Lakeville.	Gravity and Pumping Direct.	Holly, Allis.	Bituminous.		Cumberland.	3 35 3 75	8.28 0.43	
24	Troy, N. Y.	1833–99	City.	Five Artificial Storage Reservoirs and Hudson River.	Gravity and Pumping.	Holly.	Anthracite.	Buckwheat.		2 57 2 54	18.27	5 00
25	Waltham, Mass. . .	1872–73	City.	Filter Basin, near Charles River.	Pumping.	Barr, Worthington.	Bituminous.		Georges Creek.	4 14	10.	
26	Wellesley, Mass. . .	1884	Town.	Two Wells.	Pumping to Reservoir.	Blake.	Bituminous.		Georges Creek and Puritan.	4 04	10.4	3 50
27	Whitman, Mass. . .	1883–84	Town.	Well.	Pumping.	Blake, Worthington.						
28	Woonsocket, R. I. .	1884	City.	Crook Falls Brook.	Pumping to Tanks.	Deane, Worthington.	Bituminous.		Georges Creek.	4 54	6.65	3 00

1898.—TABLE 1., *Continued.*—PUMPING.

Number.	3 Coal Consumed for the Year. Lbs.	4 Lbs. of Wood ÷ 3.	5 Total Fuel Consumed for the Year. Lbs.	6 Total Pumpage for the Year in Gallons.	7 Average Static Head against which Pumps Work. Feet.	8 Average Dynamic Head against which Pumps Work. Feet.	9 Number of Gallons per Pound of Coal.	10 Duty in Foot-pounds per 100 Pounds of Coal. No Deductions.	11 Cost per Million Gallons Pumped into Reservoir, figured on Pumping Station Expenses.	12 Cost per Million Gallons raised 1 foot high, figured on Pumping Station Expenses.	13 Cost per Million Gallons Pumped into Reservoir, figured on Total Maintenance.	14 Cost per Million Gallons raised 1 foot high, figured on Total Maintenance.
1	2 427 232 843 623	. . . .	. . . . . .	691 296 932 146 300 383	81 119 5	110 5 119 5	285 173 4	26 347 500 17 283 000	$ 8 99 23 49	$0 0814 0 1915	$ 30 84	$0 275
2	516 675	1 000	517 675	130 526 640	160	175 188	252	39 400 000	22 09	0 1177	145 17	0 772
3	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
4	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
5	399 408	. .	. . .	366 187 044	. .	43	916 82	. . .	. . .	. . .	. . .	. . .
6	. . .	. .	. . .	294 118 350	289	316	. .	. . .	25 61	0 08	148 13	0 468
7	256 220	. .	. . .	124 393 311	. .	. . .	485	. . .	. . .	. . .	. . .	. . .
8	3 512 320	. .	. . .	1 144 657 850	. .	184 69	325 82	. . .	9 83	. . .	124 04	. . .
9	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
10	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
11	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
12	9 057 728	2 400	9 060 128	3 517 663 230	156 33	163 77	275	79 360 607	. . .	. . .	. . .	. . .
13	235 900 2 517 160	1 310	235 900 2 518 470	133 450 140 1 598 126 150	. . . .	167 52 164 22	565 70 634 80	79 035 791 86 954 554	6 04	0 0367	72 65	0 4428
14	475 650	. .	475 650	78 163 000	180	201	164 33	27 514 066	31 11	0 155	86 61	0 4325
15	1 344 100 527 300 1 248 600	152 71 73	1 344 252 527 371 1 248 673	910 443 881 241 975 116 1 024 833 324	124 7 131 62 124 9	134 02 133 20 127 26	677 459 821	75 702 140 50 971 186 87 108 891	5 44	0 0416	52 54	0 4018
16	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
17	1 536 400	8 000	1 544 400	640 373 316	234	254	414	92 000 000	11 99	0 047	178 00	0 70
18	272 000	. .	. . .	29 210 000	80	80	108	7 165 000	47 90	0 60	168 50	2 11
19	230 332	14 100	244 432	111 567 456	65	66	484 37	26 661 662	13 50	0 20	81 83	1 24
20	*w* 5 242 600 *h* 908 420	450 1 362	5 243 050 909 782	3 552 860 464 538 771 535	170 3 112	175 88 139	678 593	99 397 800 68 651 200	4 32 15 35	0 0245 0 1038	. . . . . .	. . . . . .
21	359 119	. .	359 119	41 074 585	219	240	115	. . .	91 07	0 379	340 89	1 42
22	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
23	740 600 331 000	. . . .	740 600 331 000	475 817 605	. .	61 69	642 48	33 055 035	10 01	0 1623	107 05	1 735
24	12 119 578	. .	. . .	3 108 279 059	231	242	256 47	51 762 342	11 50	0 0475	. . .	. . .
25	1 981 355	. .	. . .	620 034 502	164	180	288 615	46 977 840	15 47	0 086	68 00	0 378
26	433 480	120	433 600	60 869 466	250	278	140	32 479 785	39 70	0 142	278 63	1 002
27	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
28	961 900	502	962 402	269 628 974	238	239	. .	55 962 698	13 60	0 057	111 86	0 46

w Worthington. *h* Holly.

Number.	Name of City or Town.	Receipts from Consumers. A Rates. Domestic.	B Rates. Manufacturing.	C Net Receipts for Water.	D Miscellaneous Receipts.	E Total Receipts.
1	Atlantic City, N. J.	. . .	. . .	$ 65 888 70	$ 5 742 20	$ 71 630 90
2	Attleboro, Mass.	. . .	. . .	16 394 18	. . .	16 394 18
3	Billerica, Mass.	. . .	. . .	. . .	. . .	. . .
4	Boston, Mass. { Cochituate	. . .	. . .	. . .	. . .	. . .
	Boston, Mass. { Mystic	. . .	. . .	. . .	. . .	. . .
5	Brockton, Mass.	[1] $ 48 166 64	[2] $ 8 010 32	56 176 96	1 456 44	57 633 40
6	Burlington, Vt.	37 241 45	2 874 41	40 115 86	637 64	40 753 50
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	[1] 142 025 27	[2] 5 242 33	147 267 60	4 007 51	151 275 11
9	Fitchburg, Mass.	50 957 40	15 316 09	66 273 49	. . .	66 273 49
10	Holyoke, Mass.	[1] 12 776 63	[2] 66 168 94	78 945 57	7 059 13	86 004 70
11	Keene, N. H.	. . .	. . .	. . .	. . .	. . .
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	119 251 45	57 139 78	176 391 23	9 959 07	186 350 30
14	Middleboro, Mass.	[1] 6 866 56	[2] 4 121 89	10 988 45	142 27	11 130 72
15	New Bedford, Mass.	93 657 79	6 459 08	100 116 87	95 00	100 211 87
16	New London, Conn.	. . .	. . .	. . .	. . .	44 539 19
17	Newton, Mass.	[1] 91 345 76	[2] 21 925 35	. . .	. . .	. . .
18	Oberlin, Ohio	4 242 73	328 00	4 570 73	133 31	4 704 04
19	Plymouth, Mass.	19 060 18	1 550 62	20 610 80	308 11	20 918 91
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	6 227 43	182 14	6 409 57	136 18	6 545 75
22	Springfield, Mass.	[1] 61 689 54	[2] 134 921 41	196 610 95	18 211 34	214 822 29
23	Taunton, Mass.	39 925 62	12 039 12	51 964 74	403 08	52 367 82
24	Troy, N. Y.	[1] 21 423 89	[2] 73 894 17	95 318 06	7 229 31	102 547 37
25	Waltham, Mass.	54 230 29	6 242 45	60 472 74	4 500 54	64 973 28
26	Wellesley, Mass.	11 097 79	362 88	11 460 67	74 81	11 535 48
27	Whitman, Mass.	[1] 4 209 74	[2] 2 512 50	6 722 24	642 29	7 364 53
28	Woonsocket, R. I.	34 239 99	6 183 81	40 423 80	138 95	40 562 75

[1] Meter Rates. [2] Faucet or Schedule Rates.

1898.—TABLE II., *Continued.*—FINANCIAL.—MAINTENANCE.

Number.	Receipts from Public Funds. F Hydrants.	G Fountains.	H Street Watering.	I Public Buildings.	J General Appropriation or Miscellaneous.	Total from Public Funds.	K Gross Receipts.	Expenditures. AA Management and Repairs.	BB Interest on Bonds.	CC Total Maintenance for the Year.	DD Balance.	EE Total.
1	...	...	...	...	$30 000 00	$30 000 00	$101 630 90	$31 340 49	$ 43 520 00	$ 74 860 49	[1] $24 500 00 2 270 41	$101 630 90
2	...	...	...	...	7 208 34	7 208 34	23 602 52	6 888 56	12 060 00	18 948 56	[1] 4 650 00 3 96	23 602 52
3	...	...	...	...	...	...	...	...	...	...	...	...
4	...	...	...	...	...	...	...	...	...	...	...	...
5	$ 3 000 00	...	$1 000 00	...	...	4 000 00	61 633 40	9 477 48	31 302 50	40 779 98	[1] 20 853 42	61 633 40
6	3 480 00	$ 250 00	1 877 28	$ 235 70	...	5 842 98	46 956 48	33 196 80	10 365 00	43 561 80	[1] 2 360 25 674 43	46 596 48
7	...	...	...	...	...	...	...	...	...	...	...	...
8	...	...	...	...	...	...	...	45 331 53	103 490 00	148 821 53	...	...
9	...	...	...	...	...	...	...	22 399 01	...	...	...	...
10	...	...	...	...	...	...	...	32 137 17	25 000 00	57 137 17	[1] 500 00	...
11	...	...	...	...	...	...	...	...	...	...	...	...
12	...	...	...	...	...	...	...	...	...	...	...	...
13	...	...	...	...	...	...	186 350 30	50 953 24	74 846 24	125 799 48	[1] 60 550 82	186 350 30
14	...	...	...	...	...	2 000 00	13 130 72	4 245 30	2 540 00	6 785 30	[2] 2 141 64 [1] 3 100 00	12 026 94
15	...	...	...	...	87 000 00	87 000 00	187 211 87	34 398 79	80 000 00	114 398 79	* [1] 29 600 00 [2] 23 213 08	187 211 87
16	11 400 00	150 00	3 600 00	225 00	...	15 375 00	59 914 19	6 927 31	24 540 00	31 467 31	[2] 28 446 88	59 914 19
17	...	...	...	...	...	...	...	17 987 62	96 000 00	...	...	...
18	...	...	...	...	4 676 89	4 676 89	9 380 93	2 424 00	2 499 08	4 923 08	[2] 1 457 85 [1] 3 000 00	9 380 93
19	...	...	...	...	...	...	20 918 91	9 385 13	3 654 40	13 039 53	** [2] 2 739 38	20 918 91
20	...	...	...	...	...	...	...	...	...	...	...	...
21	3 630 00	...	...	...	2 230 00	5 860 00	...	5 376 87	8 600 00	13 976 87	...	...
22	18 620 00	1 680 00	5 099 71	5 642 28	...	31 041 99	...	21 631 68	92 500 00	...	...	...
23	2 500 00	2 411 21	800 00	367 66	1 692 74	7 771 61	60 139 43	22 327 82	28 608 00	50 935 82	[1] 9 203 61	60 139 43
24	...	...	...	...	...	...	102 547 37	58 852 37	9 960 00	68 812 37	[1] 19 650 00 [2] 14 085 00	102 547 37
25	...	...	...	...	...	...	64 973 28	24 257 59	17 920 00	42 177 59	[1] 22 172 12 623 57	64 973 28
26	4 720 00	400 00	200 00	199 45	...	5 519 45	17 054 93	6 180 13	10 780 00	16 960 13	...	...
27	3 200 00	...	...	...	...	3 200 00	10 564 53	3 888 73	4 000 00	7 888 73	[2] 2 675 80	10 564 53
28	15 475 00	1 627 99	1 780 06	885 69	11 257 85	31 026 59	71 589 34	11 298 52	18 871 24	30 169 76	41 419 58	71 589 34

[1] To Sinking Fund. [2] To Construction. * Bonds paid, $20,000.00. ** Bonds paid, $5,140.00.

1898.—TABLE II., *Continued.*—FINANCIAL.—CONSTRUCTION AND MISCELLANEOUS.

Number.	Name of City or Town.	Receipts. R Balance from Previous Year.	S Bonds Issued.	T Appropriations from Tax Levy.	U Other Sources.	V Total.
1	Atlantic City, N. J.	. . .	. . .	$ 2 500 00	$ 198 80	$ 2 698 80
2	Attleboro, Mass.	$ 2 778 90	$14 820 00	. . .	154 69	17 753 59
3	Billerica, Mass.	. . .	. . .	. . .	. . .	. . .
4	Boston, Mass. { Cochituate / Mystic	. . . / . . .	. . . / . . .	. . . / . . .	. . .	. . .
5	Brockton, Mass.	13 765 00	10 000 00	. . .	5 889 52	29 654 52
6	Burlington, Vt.	. . .	. . .	3 485 22	. . .	3 485 22
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	6 444 67	25 000 00	7 000 00	. . .	38 444 67
9	Fitchburg, Mass.	. . .	. . .	. . .	4 083 53	4 083 53
10	Holyoke, Mass.	. . .	. . .	. . .	. . .	. . .
11	Keene, N. H.	. . .	. . .	. . .	. . .	. . .
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	11 277 06	35 000 00	. . .	3 002 19	49 279 25
14	Middleboro, Mass.	[1] 2 141 64	. . .	. . .	484 17	2 625 81
15	New Bedford, Mass.	{ 40 125 71 / [1] 23 213 08 }	. . .	. . .	7 278 63	70 617 42
16	New London, Conn.	{ 52 338 69 / [1] 28 446 88 }	. . .	. . .	. . .	80 785 57
17	Newton, Mass.	. . .	41 037 23	. . .	1 563 56	42 600 79
18	Oberlin, Ohio	281 10	. . .	. . .	1 757 20	2 038 30
19	Plymouth, Mass.	{ [1] 2 739 38 / 2 743 61 }	. .	. . .	255 50	5 738 49
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	6 439 43	7 730 20	. . .	517 21	14 686 84
22	Springfield, Mass.	. . .	. . .	. . .	. . .	. . .
23	Taunton, Mass.	1 220 27	20 000 00	. . .	3 268 72	24 488 99
24	Troy, N. Y.	{ 6 645 16 / [1] 14 085 00 }	. . .	. . .	. . .	20 730 16
25	Waltham, Mass.	19 761 40	5 000 00	. . .	6 931 05	31 692 45
26	Wellesley, Mass.	3 795 52	7 000 00	. . .	1 969 91	12 765 43
27	Whitman, Mass.	{ [1] 2 675 80 / 1 211 75 }	. . .	. . .	10 75	3 898 30
28	Woonsocket, R. I.	. . .	. . .	10 918 93	2 084 00	13 002 93

[1] From Maintenance Account.

1898.—TABLE II., *Continued.*—FINANCIAL.—CONSTRUCTION AND MISCELLANEOUS.

Number.	Expenditures.						Miscellaneous.			
	FF	GG	HH	II	JJ	KK	W	X	Y	Z
	Extensions.		Special.	Total for Year.	Balance.	Total.	Net Cost of Works to Date.	Bonded Debt to Date.	Value of Sinking Fund to Date.	Rate of Interest, Per Cent.
	Mains.	Services.								
1	$ 2 668 27	. . .	. . .	$ 2 668 27	$ 30 53	$ 2 698 80	$ 893 309 50	$ 887 000 00	$ 55 141 63	4.937
2	. . .	. . .	. . .	11 968 50	5 785 09	17 753 59	335 527 47	278 000 00	47 442 96	. . .
3	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5	14 318 59	. . .	$ 5 713 82	20 032 41	9 622 11	29 654 52	864 495 45	770 000 00	264 506 11	4
6	2 899 75	$ 585 47	. . .	3 485 22	. . .	3 485 22	463 113 31	258 500 00	181 572 88	4
7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	25 000 00	. . .	13 444 67	38 444 67	. . .	38 444 67	. . .	1 950 000 00	549 591 70	5.3
9	1 182 75	6 596 14	1 183 75	8 962 64	. . .	. . .	484 874 66	636 000 00	151 125 34	4.3
10	33 388 72	. . .	. . .	. . .	. . .	. . .	1 118 259 63	500 000 00	289 190 50	. . .
11	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
13	4 262 16	4 290 39	27 310 86	35 863 41	13 415 84	49 279 25	2 396 788 65	1 835 300 00	486 692 08	3.5 to 5
14	1 874 79	656 33	94 69	2 625 81	. . .	2 625 81	113 283 87	61 500 00	4 015 71	4
15	28 432 80	6 344 51	. . .	34 777 31	35 840 11	70 617 42	1 775 427 75	560 000 00	91 012 12	4.49
16	21 857 14	1 316 07	14 117 04	37 290 25	43 495 32	80 785 57	667 008 32	426 000 00	. . .	7 and 4
17	. . .	. . .	. . .	. . .	. . .	42 600 79	2 054 251 23	2 075 000 00	735 346 06	4.7
18	1 180 10	858 20	. . .	2 038 30	. . .	2 038 30	82 442 72	50 000 00	68 93	4.5 & 5.75
19	449 51	754 57	1 785 03	2 989 11	2 749 38	5 738 49	259 655 55	87 740 00	. . .	4
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
21	1 797 52	1 287 89	9 975 03	13 060 44	. . .	. . .	244 131 16	215 000 00	. . .	4
22	16 042 36	. . .	1 201 58	17 243 94	. . .	. . .	2 083 480 52	1 550 000 00	332 886 64	5.91
23	12 878 99	8 211 39	2 412 56	23 502 94	986 05	24 488 99	1 195 542 95	725 200 00	106 077 22	4
24	11 164 31	. . .	. . .	11 164 31	9 565 85	20 730 16	1 293 094 51	246 000 00	42 962 50	4
25	. . .	. . .	. . .	24 874 47	6 817 98	31 692 45	. . .	406 000 00	49 601 67	4
26	2 900 74	1 314 30	6 015 16	10 230 20	. . .	. . .	306 107 06	275 000 00	70 080 31	4
27	. . .	. . .	. . .	1 663 70	2 234 60	3 898 30	125 889 04	100 000 00	. . .	4
28	10 918 93	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

1898. — TABLE III. — CONSUMPTION.

Number.	Name of City or Town.	1 Estimated Population. Total at Date.	2 On Line of Pipe.	3 Supplied at Date.	4 Total Gallons Consumed for the Year.	5 Quantity Used through Domestic Meters. Gallons.	6 Quantity Used through Manufacturing Meters. Gallons.	Percentage of Total Consumption Metered.	7 Average Daily Consumption. Gallons.	8 Gallons per Day. Each Inhabitant.	9 Each Consumer.	10 Each Tap.
1	Atlantic City, N. J.	25 000	24 500	. .	837 597 315	. . .	. . .	. .	. . .	50	. .	622
2	Attleboro, Mass.	8 900	7 400	6 900	130 526 640	. . .	. . .	. .	357 688	40 1	51 8	. .
3	Billerica, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
4	Boston, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
5	Brockton, Mass.	35 000	33 200	31 600	366 187 044	141 013 762	37 325 625	. .	1 003 252	28 66	31 11	202 39
6	Burlington, Vt.	18 000	17 600	17 400	294 118 350	120 979 500	14 785 500	46	805 800	45	46	251
7	Concord, N. H.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
8	Fall River, Mass.	97 517	. .	94 267	1 144 657 850	. . .	. . .	. .	3 136 049	32 16	33 26	. .
9	Fitchburg, Mass.	29 000	25 000	23 000	940 000 000	72 400 000	285 000 000	. .	. . .	91	122	604
10	Holyoke, Mass.	44 982	44 482	43 982	1 375 000 000	198 907 750		. .	3 769 093	83 79	85 69	1 076
11	Keene, N. H.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
12	Lowell, Mass.	. . .	. .	. .	2 454 575 265	. . .	. . .	. .	6 724 865	. .	78	. .
13	Lynn, Mass.	70 700	. .	68 000	1 732 220 852	260 000 000		. .	4 745 810	. .	69 79	. .
14	Middleboro, Mass.	Town 7 000; F. Dist. 4 200	4 000	3 750	78 163 000	11 328 848	25 603 436	. .	214 145	51	57 12	278 5
15	New Bedford, Mass.	58 000	51 000	50 000	2 156 277 643	68 100 337	246 866 887	14 6	5 907 610	102	118	655
16	New London, Conn.	15 800	15 300	14 800	472 064 049	. . .	. . .	. .	1 293 320	82	87	447 2
17	Newton, Mass.	30 000	29 600	29 400	641 589 600	293 000 000	44 000 000	. .	1 757 780	58 6	59 8	259
18	Oberlin, Ohio	4 700	3 500	2 500	29 210 000	8 875 000	1 640 000	35	80 000	17	32	142
19	Plymouth, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
20	Providence, R. I.	170 200	. .	. .	3 339 382 586	. . .	. . .	. .	9 148 993	54	. .	447
21	Reading, Mass.	4 750	4 160	3 650	41 074 585	. . .	. . .	. .	112 533	23 69	30 83	161 2
22	Springfield, Mass.	57 676	50 800	45 500	1 877 012 500	405 371 533		21 6	5 142 500	89	113	567
23	Taunton, Mass.	27 693	26 950	26 840	475 817 605	64 594 282	126 584 192	. .	1 303 610	48	48 6	308
24	Troy, N. Y.	65 000	61 000	58 000	3 929 001 559	410 356 723		. .	10 764 388	165	185	1 472
25	Waltham, Mass.	22 400	21 600	21 200	620 034 502	32 822 478		. .	1 698 425	76	80	532
26	Wellesley, Mass.	4 229	4 024	3 874	60 869 466	38 264 515	762 622	. .	166 765	39	43	207
27	Whitman, Mass.	6 000	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
28	Woonsocket, R. I.	28 500	26 500	26 000	269 565 879	. . .	. . .	. .	748 107	26	28	372

1898.—TABLE IV.—DISTRIBUTION.—MAIN PIPES.

Number.	Name of City or Town.	1 Kind of Pipe.	2 Size of Pipe. Inches.	3 Length Extended During the Year in Feet.	4 Length Discontinued During the Year in Feet.	5 Total Length in Use. Miles.	6 Cost of Repairs per Mile.	7 Number of Leaks for Year.	8 Length of Pipe Less than 4 in. Diam. Miles.	9 Hydrants. Number Added.	10 Hydrants. Total in Use.	11 Gates. Number Added.	12 Gates. Total in Use.	13 Gates. Number less than 4 Inch.	14 Gates. Number Blow-off Gates.	15 Range of Pressure on Mains at Center for Day and Night. Pounds.
1	Atlantic City, N. J. .	C. I.	4 to 20	5 784	0	42 65	. .	. .	2 0	11	436	. .	. .	. .	9	. . .
2	Attleboro, Mass. . .	C. I., C. L.	4 to 16	2 466	. .	30 28	. .	12	. .	9	245	. .	. .	. .	. .	54 to 62
3	Billerica, Mass. . . .	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .
4	Boston, Mass. { Cochituate	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .
	{ Mystic . .	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .
5	Brockton, Mass. . .	W. I., C. L., C. I.	6 to 30	7 426	1 012	62 49	$ 0 47	[1]0 09	. .	11	576	22	707	. .	19	47 to 56
6	Burlington, Vt. . . .	C. L., C. I., W. I.	4 to 30	3 833	7 837	37 0	8 50	[1]0 22	2 6	2	205	49	573	56	12	70 to 85
7	Concord, N. H. . . .	. . .	¾ to 20	13 505	3 834	59 22	. .	. .	. .	7	260	23	720	. .	. .	. . .
8	Fall River, Mass. . .	C. I.	6 to 24	. .	. .	84 8	. .	. .	. .	30	912	44	905	. .	. .	80
9	Fitchburg, Mass. . .	W. I., C. L., C. I.	2 to 30	1 577	. .	63 72	1 97	6	1 33	8	447	9	528	. .	. .	{ 155 to 160 { 75 to 80
10	Holyoke, Mass. . . .	W. I., C. I.	½ to 30	81 067	0	78 37	2 52	2	5 62	60	807	129	674	1	25	{ 45 to 65 { 80 to 100
11	Keene, N. H.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .
12	Lowell, Mass.	C. I.	. .	14 046	. .	124	. .	. .	. .	12	1 123	46	1 144	. .	. .	. . .
13	Lynn, Mass.	W. I., C. L., C. I.	2 to 20	2 232	. .	109 6	. .	115	. .	1	794	6	948	. .	. .	50 to 65
14	Middleboro, Mass. .	C. I.	4 to 12	1 112	. .	16 17	. .	0	. .	2	114	4	158	. .	5	45 to 60
15	New Bedford, Mass.	C. I.	4 to 36	16 033	6 403	89 33	14 81	8	1 18	20	713	38	1 012	72	93	28 to 39
16	New London, Conn.	C. I., W. I., C. L.	4 to 20	5 726	0	46 1	17 37	[1]0 69	3 1	16	228	15	274	. .	30	45 to 50
17	Newton, Mass. . . .	C. I.	4 to 20	15 736	1 000	133 6	13 50	6	0 22	24	903	39	774	46	360	84
18	Oberlin, Ohio	C. I.	4 to 12	1 668	0	8 8	0	0	0 33	3	83	2	53	2	2	27 to 32
19	Plymouth, Mass. . .	W. I., C. L.	2 to 20	855	0	35 17	5 55	[1]1 00	10 5	0	120	2	327	130	22	. . .
20	Providence, R. I. . .	{ Low Serv., C. I.	6 to 36	26 162	2 365	314 85	. .	. .	0	28	1 815	75	3 286	32	. .	64 to 73
		{ High Serv. Fire, C. I.	12, 16, 24	. .	. .	5 57	. .	. .	. .	2	91	. .	31	4	. .	114
21	Reading, Mass. . . .	C. I.	4 to 12	3 139	0	23 61	0	0	0	4	125	5	212	0	14	68 to 78
22	Springfield, Mass. . .	{ W. I., W. I. C. L., C. I. }	1 to 36	38 944	10 610	140 08	7 87	0 56	7 43	39	931	80	1 763	318	86	{ 100 to 120 { 30 to 35
23	Taunton, Mass. . . .	C. I.	4 to 30	11 827	0	75 94	35 83	3	1 3	20	761	22	529	12	52	45 to 50
24	Troy, N. Y.	C. I.	4 to 30	9 515	545	60 63	2 94	22	0 53	20	782	60	1 332	. .	37	9 to 107
25	Waltham, Mass. . .	C. I., W. I., C. L.	2 to 24	3 966	. .	50	4 23	[1]0 5	. .	13	319	10	643	. .	. .	58
26	Wellesley, Mass. . .	C. I.	4 to 12	1 994	0	28 38	1 19	[1]0 3	0 5	5	249	2	197	9	4	70
27	Whitman, Mass. . .	C. L., C. I.	. .	644	. .	16 5	. .	. .	. .	0	147	1	85	. .	. .	65
28	Woonsocket, R. I. .	C. I.	4 to 20	7 323	. .	44 8	2 20	[1]19 00	0	12	535	17	443	. .	16	50 to 120

[1] Per mile.

1898.—TABLE V.—DISTRIBUTION.—SERVICE PIPES.

Number.	Name of City or Town.	16 Service Pipe. Kind.	17 Service Pipe. Size. Inches.	18 Service Pipe. Extended. Feet.	19 Service Pipe. Discontinued. Feet.	20 Service Pipe. Total in Use. Miles.	21 Service Taps. Added.	22 Service Taps. Total in Use.	23 Average Length of Services.	24 Average Cost of Services.	25 Meters. Added.	26a Meters. Now in Use. Domestic.	26b Meters. Now in Use. Manufacturing.	27 Motors and Elevators. Added.	28 Motors and Elevators. Total in Use.
1	Atlantic City, N. J.	C. I., L., G. I., T. L. G. I.	½ to 4	. .	. .	. .	. . .	. . .	. .	. .	501	2 636		.	. . .
2	Attleboro, Mass.	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	48	788		.	2
3	Billerica, Mass.	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	.	. .	.	.	. .
4	Boston, Mass. { Cochituate	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	.	. .	.	.	. .
	{ Mystic	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	.	. .	.	.	. .
5	Brockton, Mass.	W. I., L. L., C. L., C. I.	¾ to 6	7 813	277	27 81	128	4 957	56 2	. .	222	3 923		.	. .
6	Burlington, Vt.	G. I., L.	½ to 6	1 800	60	17	67	3 202	27	$ 7 60	162	1 926	37	2	35
7	Concord, N. H.	. . .	. .	1 665	. .	14 42	68	3 240	. .	. .	152	778		.	. .
8	Fall River, Mass.	Lead.	½ to 2	. .	. .	. .	154	6 576	. .	. .	174	6 128		.	. .
9	Fitchburg, Mass.	W. I., C. L., C. I.	¾ to 8	4 456	. .	46 27	96	4 265	57	20	146	1 982	195	4	84
10	Holyoke, Mass.	C., R. L., Enam., C. I., L. L.	⅝ to 4	1 240	5	13 26	62	3 501	20	14 56	9	208		3	48
11	Keene, N. H.	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	.	. .	.	.	. .
12	Lowell, Mass.	. . .	. .	6 534	. .	. .	165	. . .	. .	. .	482	4 866		.	. .
13	Lynn, Mass.	L., C. L., Adam., G. I., L. L.	¾ to 10	5 446	820	93 3	98	11 452	. .	. .	206	2 074		.	. .
14	Middleboro, Mass.	W. I. C. L., L.	¾ to 3	1 211	. .	8 5	22	769	55	. .	22	310		0	6
15	New Bedford, Mass.	L., C. I.	½ to 10	12 226	260	58 79	154	9 014	47	27 59	113	669	62	.	104
16	New London, Conn.	W. I. C. L., G., C. I., L.	½ to 4	1 490	0	10 6	81	2 892	19	10 76	11	208		1	17
17	Newton, Mass.	L., W. I., C. I.	½ to 6	13 200	4 100	75 5	198	6 771	58	22 50	329	5 429	25	0	17
18	Oberlin, Ohio	G. I., L.	¾ to 2	. .	. .	. .	30	565	25	8	46	253	5	0	0
19	Plymouth, Mass.	L., C. L.	½ to 1	420	. .	5 74	47	1 758	17 67	4 60	.	. .	.	0	1
20	Providence, R. I.	L., C. I.	½ to 10	. .	. .	. .	566	20 473	. .	. .	709	16 388		8	146
21	Reading, Mass.	G. I., C. L. I., L. L. I., C. I.	¾ to 6	2 567	0	11 67	41	928	62 60	31 41	665	851		0	3
22	Springfield, Mass.	W. I. (Tarred & Galv.), C. I.	½ to 6	. .	. .	. .	349	9 070	. .	. .	231	2 727		28	202
23	Taunton, Mass.	C. L. W. I., T. L. W. I.	¾ to 3	6 917	6 054	40 98	146	4 233	. .	38 44	87	1 469	154	0	14
24	Troy, N. Y.	Lead, C. I.	¾ to 6	. .	. .	. .	264	7 309	35	25	23	292		.	. .
25	Waltham, Mass.	C. I., W. I. C. L.	¾ to 10	7 271	148	36 8	55	3 192	130	107 82	0	72		0	6
26	Wellesley, Mass.	C. I., W. I. C. L., I.	½ to 6	2 324	. .	13 65	29	795	80	9 86	21	732	5	0	2
27	Whitman, Mass.	. . .	. .	. .	. .	. .	22	925	. .	. .	.	425		.	. .
28	Woonsocket, R. I.	Lead, Iron.	⅝ to 6	1 028	. .	5 91	68	2 010	18 72	14 07	93	1 722	56	0	12

1899.—TABLE I.—GENERAL AND PUMPING.

Number.	Name of City or Town.	Date of Construction.	By whom Owned.	Source of Supply.	Mode of Supply.	1	2.—Description of Coal Used.					
						Builders of Pumping Machinery.	*b* Kind.	*c* Size.	*d* Brand.	*e* Price per Ton.	*f* Per Cent. of Ash.	*g* Wood. Price per Cord.
1	Atlantic City, N. J.											
2	Attleboro, Mass. . .	1873	Town.	Well near Seven Mile River.	Pumping to Standpipe.	Deane, Barr.	Bituminous.		Georges Creek.	$4 25		
3	Billerica, Mass. . . .	1898		Driven Wells.	Pumping to Mains and to Standpipe.	Barr.	Bituminous.		Georges Creek.			
4	Boston, Mass. . . .											
5	Brockton, Mass. . .	1880	City.	Storage Reservoirs.	Pumping to Standpipe.	Worthington, Holly.						
6	Burlington, Vt. . . .	1867–68	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.		Reynoldsville.	2 67½		
7	Concord, N. H. . . .											
8	Fall River, Mass. . .	1874	City.	Watuppa Lake.	Pumping to Standpipe and Tanks.	Worthington. Davidson.			Georges Creek.			
9	Fitchburg, Mass. . .	1873	City.	Storage Reservoirs.	Gravity.							
10	Holyoke, Mass. . . .											
11	Keene, N. H.	1868	City.	Sylvan and Echo Lakes.								
12	Lowell, Mass.	1870–96	City.	Driven Wells.	Pumping to Reservoir and Direct.	Morris, Worthington, Deane, Knowles.	Bituminous.	Broken.	Cumberland.	3 85		
13	Lynn, Mass.											
14	Middleboro, Mass. .	1885	F. Dist.	Well.	Pumping to Reservoir and Direct.	Deane.	Bituminous.		Georges Creek & Pocahontas.	3 85		

15	New Bedford, Mass.	1866–'99	City.	Little Quittacas Pond.	Pumping to Reservoir and Gravity.	McAlpine, Worthington, Leavitt,	Bituminous.		Pocahontas.	$3 50 3 75 4 00	7	$4 00
16	New London, Conn.	1872	City.	Lake Kononoc.								
17	Newton, Mass. . . .	1876	City.	Filter Basin fed by Springs and Driven Wells.	Pumping to Reservoir through Mains.	Blake, Worthington.	Bituminous.	Broken.	Georges Creek.	4 50	8	6 00
18	Oberlin, Ohio	1887	Village.	East Branch Vermillion River.	Pumping.	Deane.	Bituminous.	Run of Mine.	Pocahontas.	3 36		
19	Plymouth, Mass. . .	1855	Town.	Great and Little South and Lout Ponds.	Gravity and Pumping.	Worthington.	Bituminous.	Various		5 00		
20	Providence, R. I. . .	1870–76	City.	Pawtuxet River.	Gravity and Pumping.	Worthington, Cornish, Corliss, Nagle and Holly.	Bituminous and Anthracite.	Egg.	Georges Creek & Reading.	3 98 5 04 5 17		4 50 5 00 5 00
21	Reading, Mass. . . .	1890–91	Town.	Filter Gallery.	Pumping to Standpipe.	Blake.	Bituminous.		Georges Creek.	4 60		
22	Springfield, Mass. .	1864–94	City.	Impounding Reservoirs.	Gravity.							
23	Taunton, Mass. . . .	1876	City.	Elder's Pond and Assowompsett Pond.	Gravity and Pumping.	Holly, Allis.	Bituminous.		Cumberland.	3 35 3 75	8.28 0.43	
24	Troy, N. Y.	1833–99	City.	Five Artificial Storage Reservoirs and Hudson River.	Gravity and Pumping.	Holly.	Anthracite.	Buckwheat.		2 57 2 40	17.24	5 00
25	Waltham, Mass. . .	1872–73	City.	Filter Basin, near Charles River.	Pumping.	Barr, Worthington.	Bituminous.		Georges Creek.	3 90	10	
26	Wellesley, Mass. . .	1884	Town.	Wells.	Pumping to Reservoir.	Blake.	Bituminous.		Georges Creek, Puritan.	4 00	9.3	3 50
27	Whitman, Mass. . .	1883–84	Town.	Well.	Pumping.	Blake, Worthington.						
28	Woonsocket, R. I. .	1884	City.	Crook Falls Brook.	Pumping to Tanks.	Deane, Worthington.	Bituminous.		Georges Creek.	4 08	6.5	3 00

1899.—TABLE 1., *Continued.*—GENERAL AND PUMPING.

	3	4	5	6	7	8	9	10	11	12	13	14
Number.	Coal Consumed for the Year. Lbs.	Lbs. of Wood ÷ 3.	Total Fuel Consumed for the Year. Lbs.	Total Pumpage for the Year in Gallons.	Average Static Head against which Pumps Work. Feet.	Average Dynamic Head against which Pumps Work. Feet.	Number of Gallons per Pound of Coal.	Duty in Foot-pounds per 100 Pounds of Coal. No Deductions.	Cost per Million Gallons Pumped into Reservoir, figured on Pumping Station Expenses.	Cost per Million Gallons raised 1 foot high, figured on Pumping Station Expenses.	Cost per Million Gallons Pumped into Reservoir, figured on Total Maintenance.	Cost per Million Gallons raised 1 foot high, figured on Total Maintenance.
1	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
2	547 821	1 000	548 821	133 157 440	160	188	244	38 300 000	$22 15	$0 118	$168 70	$0 898
3	215 787	. .	. . .	14 727 118	. .	. . .	172	17 519 482	. . .	. . .	. . .	. . .
4	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
5	413 868	. .	. . .	415 075 817	. .	43	1 002 91	. . .	. . .	. . .	. . .	. . .
6	. . .	. .	. . .	308 912 525	289	316	. .	. . .	19 91	0 06	119 92	0 379
7	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
8	3 991 680	. .	. . .	1 307 026 763	. .	185 7	327 37	. . .	9 43	. . .	107 38	. . .
9	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
10	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
11	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
12	10 173 433	2 400	. . .	2 659 052 210	156 22	163 07	266	68 621 177	8 41	0 0516	. . .	. . .
13	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
14	528 450	. .	528 450	81 811 000	182	203	154 62	26 189 036	29 73	0 1465	81 82	0 403
	1 281 100	75	1 281 175	887 751 910	124 9	134 16	693	77 530 442				
15	310 350	75	310 425	148 573 352	127 79	129 29	479	51 607 785	. . .	. . .	. . .	. . .
	476 800	0	476 800	369 980 892	125 1	127 41	776	82 454 168				
16	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	5 49	0 0116	. . .	. . .
17	2 219 000	6 000	2 225 000	743 282 000	234	254	334	70 700 000	12 59	0 019	155 02	0 61
18	360 000	. .	. . .	38 759 000	80	80	108	7 183 000	38 00	0 47	136 00	1 70
19	271 354	14 000	285 354	117 664 272	65	66	433 61	23 867 628	14 76	0 22	102 70	1 60
	5 395 900	300	5 396 200	3 692 751 000	170 39	176 46	684	100 710 400				
20	43 014	40	43 054	22 749 951	110 08	117 23	529	51 662 100	4 27	0 0242	. . .	. . .
	788 971	1 017	789 988	504 259 180	111 96	126 42	639	67 326 600	14 90	0 1085	. . .	. . .
21	392 661	. .	392 661	47 971 992	219	240	122	. . .	51 53	0 2147	292 80	1 22
22	. . .	. .	. . .	. . .	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
23	830 100	. .	830 100	526 759 797	. .	61 65	635 17	32 627 315	9 84	0 1596	96 97	1 57
24	12 477 895	. .	. . .	2 787 764 573	231	242	223 42	45 091 656	11 71	0 0484	. . .	. . .
25	1 376 005	. .	. . .	739 981 774	164	180	270 671	82 377 990	13 15	0 073	53 70	0 30
26	456 102	98	456 200	77 456 293	250	278	169	39 368 701	24 68	0 089	221 92	0 798
27	. . .	. .	. . .	59 058 124	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
28	1 101 150	251	1 101 401	292 314 210	238	239	. .	52 915 497	12 75	0 053	104 25	0 43

1899. — TABLE II. — FINANCIAL. — MAINTENANCE.

Number.	Name of City or Town.	Receipts from Consumers. A Rates. Domestic.	B Rates. Manufacturing.	C Net Receipts for Water.	D Miscellaneous Receipts.	E Total Receipts.
1	Atlantic City, N. J.	. . .	. . .	. . .	. . .	. . .
2	Attleboro, Mass.	. . .	. . .	$ 19 968 89	. . .	. . .
3	Billerica, Mass.	$ [1] 829 73	$ [2] 1 182 29	2 012 02	$ 128 87	$ 2 140 89
4	Boston, Mass. Cochituate	. . .	. . .	. . .	. . .	. . .
	Boston, Mass. Mystic	. . .	. . .	. . .	. . .	. . .
5	Brockton, Mass.	[1] 58 046 16	[2] 8 135 02	66 181 18	7 096 66	73 277 84
6	Burlington, Vt.	39 068 93	3 334 66	42 403 59	1 533 36	43 936 95
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	[1] 148 285 71	[2] 4 620 73	152 906 44	7 455 63	160 362 07
9	Fitchburg, Mass.	[1] 39 974 93	[2] 23 343 70	. . .	. . .	. . .
10	Holyoke, Mass.	. . .	. . .	. . .	. . .	. . .
11	Keene, N. H.	. . .	. . .	. . .	. . .	21 827 37
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	. . .	. . .	. . .	. . .	. . .
14	Middleboro, Mass.	[1] 6 736 09	[2] 3 986 27	10 722 36	201 77	10 924 13
15	New Bedford, Mass.	90 243 26	8 882 01	99 125 27	61 00	99 186 27
16	New London, Conn.	. . .	. . .	. . .	. . .	45 021 70
17	Newton, Mass.	[1] 102 810 70	[2] 18 735 79	121 546 49	9 385 41	130 931 90
18	Oberlin, Ohio	4 901 78	244 00	5 145 78	515 88	5 661 66
19	Plymouth, Mass.	19 293 33	1 343 86	20 637 19	241 86	20 879 05
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	7 570 41	137 61	7 708 02	271 02	7 979 04
22	Springfield, Mass.	[1] 63 314 94	[2] 144 367 18	207 682 12	21 988 76	229 670 88
23	Taunton, Mass.	41 655 47	11 666 12	53 321 59	520 63	53 842 22
24	Troy, N. Y.	[1] 21 910 11	[2] 75 412 87	97 322 98	7 366 84	104 689 82
25	Waltham, Mass.	56 804 95	6 965 94	63 770 89	2 140 19	65 911 08
26	Wellesley, Mass.	12 677 91	231 59	12 909 50	357 71	13 267 21
27	Whitman, Mass.	4 229 95	2 803 98	7 033 93	662 44	7 696 37
28	Woonsocket, R. I.	36 461 47	7 842 35	44 303 82	99 96	44 403 78

[1] Meter Rates. [2] Faucet or Schedule Rates.

1899.—TABLE II., *Continued.*—FINANCIAL.—MAINTENANCE.

Number.	Receipts from Public Funds.							Expenditures.				
	F	G	H	I	J	Total from Public Funds.	K	AA	BB	CC	DD	EE
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.		Gross Receipts.	Management and Repairs.	Interest on Bonds.	Total Maintenance for the Year.	Balance.	Total.
1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2	. . .	. . .	. . .	. . .	$ 7 116 04	$ 7 116 04	$ 27 084 93	$ 9 847 19	$ 12 582 50	$ 22 429 69	[2]$ 4 650 00 5 24	$ 27 084 93
3	$ 2 300 00	. . .	. . .	. . .	1 000 00	3 300 00	5 440 89	1 504 69	3 600 00	5 104 69	336 20	5 440 89
4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5	3 000 00	. . .	$1 000 00	. . .	. . .	4 000 00	77 277 84	13 322 10	31 675 00	44 997 10	[2]32 280 74	77 277 84
6	3 480 00	$ 250 00	2 357 15	$ 291 97	. . .	6 379 12	50 316 07	26 856 67	10 080 00	36 936 67	[3]2 726 42 [2]7 829 11 2 823 87	50 316 07
7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	. . .	. . .	. . .	. . .	. . .	. . .	. . .	46 568 99	104 870 00	151 438 99	. . .	. . .
9	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
10	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
11	5 350 00	150 00	1 000 00	175 00	. . .	6 675 00	28 502 37	2 393 61	4 845 00	7 238 61	21 263 76	28 502 37
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
13	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
14	. . .	. . .	. . .	. . .	1 700 00	1 700 00	12 624 13	4 233 83	2 460 00	6 693 83	[2]3 000 00 [3]528 25	. . .
15	. . .	. . .	. . .	. . .	75 800 00	14 714 76 75 800 00	179 701 03	54 101 03	78 800 00	132 901 03	[2]26 800 00 [4]20 000 00	179 701 03
16	9 720 00	150 00	3 600 00	300 00	. . .	13 770 00	58 791 70	6 480 51	24 540 00	31 020 51	[3]27 771 19	58 791 70
17	. . .	. . .	. . .	. . .	. . .	. . .	130 931 90	17 253 30	97 500 00	114 753 30	16 178 60	130 931 90
18	. . .	. . .	. . .	. . .	3 963 78	3 963 78	9 625 44	3 130 22	2 139 54	5 269 76	[3]2 070 92 [2]2 284 76	9 625 44
19	. . .	. . .	. . .	. . .	. . .	. . .	20 879 05	12 190 53	3 448 80	15 639 33	[4]5 140 00 [3]99 72	20 879 05
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
21	3 750 00	300 00	. . .	. . .	2 410 00	6 460 00	14 439 04	5 507 44	8 540 00	14 047 44	391 60	14 439 04
22	19 060 00	1 680 00	5 379 12	8 095 30	. . .	34 214 42	263 885 30	22 667 04	90 750 00	113 417 04	. . .	. . .
23	2 000 00	2 499 82	800 00	454 44	4 424 90	10 179 16	64 021 38	21 471 35	29 608 00	51 079 35	[2]12 942 03	64 021 38
24	. . .	. . .	. . .	. . .	. . .	. . .	104 689 82	62 735 27	9 360 00	72 095 27	[2]19 825 00 [3]12 769 55	104 689 82
25	. . .	. . .	. . .	. . .	. . .	. . .	65 911 08	23 494 53	16 240 00	39 734 53	[2]23 216 62 2 959 93	65 911 08
26	4 560 00	400 00	200 00	116 86	596 80	5 873 66	19 140 87	5 527 74	10 940 00	16 467 74	. . .	. . .
27	2 560 00	. . .	. . .	. . .	. . .	2 560 00	10 256 37	4 286 08	4 000 00	8 286 08	[3]1 970 29	10 256 37
28	15 812 50	1 646 44	1 914 73	1 119 42	12 000 00	32 493 09	76 896 87	12 372 30	18 101 53	30 473 83	46 423 04	76 896 87

[1] From Maintenance. [2] To Sinking Fund. [3] To Construction. [4] Bonds paid.

Number.	Name of City or Town.	Receipts. R Balance from Previous Year.	S Bonds Issued.	T Appropriations from Tax Levy.	U Other Sources.	V Total.
1	Atlantic City, N. J.	. . .	. . .	. . .	. . .	. . .
2	Attleboro, Mass.	$ 5 785 09	$16 111 95	. . .	$ 23 00	$21 920 04
3	Billerica, Mass.	16 302 09	. . .	. . .	1 774 28	18 076 37
4	Boston, Mass. { Cochituate	. . .	. . .	. . .	. . .	. . .
	Boston, Mass. { Mystic	. . .	. . .	. . .	. . .	. . .
5	Brockton, Mass.	9 622 11	22 000 00	. . .	3 026 75	34 648 86
6	Burlington, Vt.	[1] 2 726 42	. . .	. . .	. . .	2 726 42
7	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
8	Fall River, Mass.	. . .	. . .	$ 6 200 00	2 169 39	8 369 39
9	Fitchburg, Mass.	. . .	. . .	. . .	. . .	. . .
10	Holyoke, Mass.	. . .	. . .	. . .	. . .	. . .
11	Keene, N. H.	. . .	. . .	. . .	. . .	. . .
12	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
13	Lynn, Mass.	. . .	. . .	. . .	. . .	. . .
14	Middleboro, Mass.	[1] 528 25	. . .	. . .	762 22	1 290 47
15	New Bedford, Mass.	35 840 11	. . .	. . .	6 585 60	42 425 71
16	New London, Conn.	{ [1] 27 771 19 37 655 82 }	. . .	. . .	. . .	65 427 01
17	Newton, Mass.	. . .	18 336 44	. . .	11 035 51	29 371 95
18	Oberlin, Ohio	. . .	. . .	. . .	2 524 68	2 524 68
19	Plymouth, Mass.	{ 2 749 38 [1] 99 72 }	. . .	. . .	2 126 27	4 975 37
20	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
21	Reading, Mass.	55 28	9 027 90	. . .	987 54	10 070 72
22	Springfield, Mass.	{ 392 27 [1] 32 095 97 }	. . .	. . .	. . .	32 488 24
23	Taunton, Mass.	986 05	30 000 00	. . .	4 900 53	35 886 58
24	Troy, N. Y.	{ [1] 12 769 55 9 565 85 }	. . .	. . .	. . .	22 335 40
25	Waltham, Mass.	6 817 98	. . .	. . .	2 329 66	9 147 64
26	Wellesley, Mass.	1 894 31	4 000 00	. . .	1 591 73	7 486 04
27	Whitman, Mass.	{ [1] 1 970 29 2 234 60 }	. . .	. . .	5 50	4 210 39
28	Woonsocket, R. I.	. . .	. . .	10 013 39	2 561 70	12 575 09

[1] From Maintenance Account.

1899.—TABLE II., *Continued.*—FINANCIAL.—CONSTRUCTION AND MISCELLANEOUS.

Number.	Expenditures.						Miscellaneous.			
	FF	GG	HH	II	JJ	KK	W	X	Y	Z
	Extensions.		Special.	Total for Year.	Balance.	Total.	Net Cost of Works to Date.	Bonded Debt to Date.	Value of Sinking Fund to Date.	Rate of Interest, Per Cent.
	Mains.	Services.								
1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2	$ 5 031 21	$1 618 71	$ 6 153 86	$12 803 78	$ 9 116 26	$21 920 04	$ 348 331 25	$ 293 000 00	$ 54 666 06	. . .
3	. . .	. . .	. . .	17 391 66	684 71	18 076 37	. . .	. . .	. . .	. . .
4	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
5	19 159 73	. . .	6 807 12	25 966 85	8 682 01	34 648 86	890 462 30	792 000 00	301 000 00	4
6	2 191 04	535 38	. . .	2 726 42	. . .	2 726 42	465 839 73	248 000 00	196 359 82	4
7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	7 169 39	. . .	1 193 84	8 363 23	6 16	8 369 39	. . .	2 000 000 00	628 968 56	5.2
9	. . .	. . .	. . .	. . .	. . .	. . .	463 193 84	636 000 00	172 806 16	. . .
10	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
11	. . .	. . .	. . .	. . .	. . .	. . .	312 934 31	. . .	. . .	. . .
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
13	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
14	492 24	798 23	. . .	1 290 47	. . .	1 290 47	113 812 12	59 500 00	5 173 39	4
15	16 904 98	7 969 05	. . .	24 874 03	[1] 4 714 76 12 836 92	42 425 71	1 800 301 78	540 000 00	121 263 77	4.48
16	13 848 74	1 412 02	9 570 30	24 831 06	40 595 95	65 427 01	691 866 18	426 000 00	. . .	7 and 4
17	. . .	. . .	. . .	29 371 95	. . .	29 371 95	2 072 587 67	2 075 000 00	787 860 98	4.7
18	795 02	1 096 23	135 69	2 026 94	497 74	2 524 68	83 880 21	49 000 00	1 284 76	3.5 & 5.75
19	1 669 53	455 90	2 849 94	4 975 37	. . .	4 975 37	266 898 78	82 600 00	. . .	4
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
21	4 180 62	3 348 52	1 700 00	9 229 14	841 58	10 070 72	252 372 73	216 000 00	. . .	4
22	10 069 22	. . .	22 026 75	32 095 97	392 27	32 488 24	2 115 576 49	1 525 000 00	378 823 07	5.89
23	8 364 16	6 094 91	14 457 31	28 916 38	6 970 20	35 886 58	1 219 558 80	755 200 00	136 807 66	4
24	6 924 89	. . .	. . .	6 924 89	15 410 51	22 335 40	1 300 019 40	236 000 00	54 112 50	4
25	. . .	. . .	. . .	8 935 06	212 58	9 147 64	. . .	406 000 00	74 190 31	4
26	3 260 34	1 149 08	2 531 47	6 940 89	545 15	7 486 04	311 456 22	269 000 00	73 007 80	4
27	. . .	. . .	. . .	1 392 81	2 817 58	4 210 39	127 281 85	100 000 00	31 281 10	4
28	. . .	. . .	. . .	10 013 39	. . .	. . .	428 128 53	. . .	. . .	. . .

[1] To Maintenance Account.

1899. — TABLE III. — CONSUMPTION.

Number.	Name of City or Town.	1 Estimated Population. Total at Date.	2 Estimated Population. On Line of Pipe.	3 Estimated Population. Supplied at Date.	4 Total Gallons Consumed for the Year.	5 Quantity Used through Domestic Meters. Gallons.	6 Quantity Used through Manufacturing Meters. Gallons.	Percentage of Total Consumption Metered.	7 Average Daily Consumption. Gallons.	8 Gallons per Day. Each Inhabitant.	9 Gallons per Day. Each Consumer.	10 Gallons per Day. Each Tap.
1	Atlantic City, N. J.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
2	Attleboro, Mass.	9 500	8 000	7 500	133 157 440	. . .	. . .	. .	364 638	38 4	46 8	. .
3	Billerica, Mass.	2 600	1 800	1 162	. . .	. . .	. . .	. .	40 183	. .	34 5	. .
4	Boston, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
5	Brockton, Mass.	38 000	36 000	34 000	415 075 817	155 038 125	50 432 925	. .	1 137 194	29 15	33 44	220 68
6	Burlington, Vt.	18 600	18 100	17 900	308 912 525	135 874 125	17 165 250	50	846 335	46	47	257
7	Concord, N. H.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
8	Fall River, Mass.	102 281	. .	98 931	1 307 026 763	. . .	. . .	. .	3 580 895	35 01	36 2	. .
9	Fitchburg, Mass.	29 000	23 000	. .	940 000 000	. . .	. . .	. .	2 600 000	. .	113	. .
10	Holyoke, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
11	Keene, N. H.	8 000	7 500	7 400	547 500 000	. . .	. . .	. .	1 500 000	188	203	884
12	Lowell, Mass.	. . .	. .	. .	2 659 464 909	. . .	. . .	. .	7 286 205	. .	81	. .
13	Lynn, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
14	Middleboro, Mass.	Town 7 000; F. Dist. 4 200	4 000	3 750	81 811 000	13 955 460	25 195 303	. .	224 140	53 37	59 75	282
15	New Bedford, Mass.	58 000	51 000	50 000	2 261 115 500	98 682 480	332 112 000	18 1	6 194 837	107	124	677
16	New London, Conn.	16 500	15 800	15 300	526 679 171	. . .	. . .	. .	1 442 957	87 5	94 3	482 6
17	Newton, Mass.	30 000	29 600	29 400	743 274 700	346 000 000	34 000 000	. .	2 036 369	67 9	68 8	293
18	Oberlin, Ohio	4 800	3 600	2 800	38 759 000	11 639 000	1 220 000	33	106 000	22	38	178
19	Plymouth, Mass.	. . .	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
20	Providence, R. I.	178 900	. .	. .	3 490 151 148	. . .	. . .	. .	9 562 058	53	. .	455
21	Reading, Mass.	4 850	4 300	4 010	47 971 992	. . .	. . .	. .	131 430	27 09	32 74	129 1
22	Springfield, Mass.	61 238	52 000	47 000	1 937 055 000	386 690 461 (domestic and manufacturing)		20	5 307 000	87	113	561
23	Taunton, Mass.	27 093	27 000	26 890	526 759 797	82 510 469	127 498 712	. .	1 443 177	53	53 7	330
24	Troy, N. Y.	65 000	61 000	58 000	3 439 764 573	406 125 475 (domestic and manufacturing)		. .	11 241 061	173	194	1 516
25	Waltham, Mass.	23 500	22 900	22 600	739 981 774	36 229 102 (domestic and manufacturing)		. .	2 027 178	86	89	620
26	Wellesley, Mass.	4 400	4 341	4 191	77 456 293	45 598 093	225 680	. .	212 209	48	51	255
27	Whitman, Mass.	. . .	. .	. .	59 058 124	. . .	. . .	. .	161 803	. .	. .	65
28	Woonsocket, R. I.	28 500	26 500	26 000	292 241 976	. . .	. . .	. .	800 922	22	28	380

1899.—TABLE IV.—DISTRIBUTION.—MAIN PIPES.

Number.	Name of City or Town.	1 Kind of Pipe.	2 Size of Pipe. Inches.	3 Length Extended During the Year in Feet.	4 Length Discontinued During the Year in Feet.	5 Total Length in Use. Miles.	6 Cost of Repairs per Mile.	7 Number of Leaks for Year.	8 Length of Pipe Less than 4 in. Diam. Miles.	9 Hydrants. Number Added.	10 Hydrants. Total in Use.	11 Gates. Number Added.	12 Gates. Total in Use.	13 Gates. Number less than 4 Inch.	14 Gates. Number Blow-off Gates.	15 Range of Pressure on Mains at Center for Day and Night. Pounds.
1	Atlantic City, N. J. .	. . .	. .	. .	. .	. .	. .	. . .	. .	. .	. .	. .	. .	. .	. .	. . .
2	Attleboro, Mass. . .	W. I., C. I., C. L.	1 to 16	1 845	. .	30 63	. .	11	. .	6	251	. .	. .	. .	. .	54 to 62
3	Billerica, Mass. . . .	C. I.	6 to 12	. .	. .	9 4	. .	3	. .	. .	94	. .	83	. .	. .	54 to 120
4	Boston, Mass. { Cochituate	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .
	{ Mystic . .	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .
5	Brockton, Mass. . .	W. I., C. L., C. I.	6 to 30	8 434	. .	64 09	$ 3 53	[1] 0 61	. .	16	592	29	747	. .	21	47 to 56
6	Burlington, Vt. . . .	C. L., C. I., W. I.	4 to 30	2 596	4 360	38 0	10 19	[1] 0 36	2 7	8	213	33	606	59	12	70 to 85
7	Concord, N. H. . . .	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .
8	Fall River, Mass. . .	C. I.	6 to 24	. .	. .	85 95	. .	. .	. .	22	934	19	924	. .	. .	80
9	Fitchburg, Mass. . .	C. I.	2 to 30	10 053	. .	65 62	. .	. .	. .	29	476	14	542	. .	. .	75 to 155
10	Holyoke, Mass. . . .	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .
11	Keene, N. H.	W. I., C. L., C. I.	4 to 24	3 140	0	35 18	4 60	[1] 0 5	3 25	3	214	5	357	. .	27	40 to 60
12	Lowell, Mass.	. . .	. .	7 847	. .	126 41	. .	. .	. .	. .	1 155	. .	1 166	. .	. .	. . .
13	Lynn, Mass.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. . .
14	Middleboro, Mass. .	C. I.	4 to 12	373	. .	16 25	. .	0	. .	0	114	3	161	. .	5	45 to 60
15	New Bedford, Mass.	C. I.	4 to 36	8 225	1 580	90 6	27 29	22	1 18	10	723	15	1 027	79	93	28 to 64
16	New London, Conn.	W. I., C. L., C. I.	4 to 24	14 384	0	48 8	9 73	24	3 0	15	243	30	304	. .	30	40 to 48
17	Newton, Mass. . . .	C. I.	4 to 20	9 430	200	135 4	8 00	4	2 9	26	930	17	790	47	368	84
18	Oberlin, Ohio	C. I.	4 to 12	2 324	0	. .	0	0	0 33	4	87	3	56	2	2	27 to 32
19	Plymouth, Mass. . .	W. I. C. L., W. I.	2 to 20	4 788	0	38	12 93	2	10 5	0	130	7	334	133	22	. . .
20	Providence, R. I. . .	{ C. I. (high pres're.)	12, 16, 24	} 19 645	769 {	5 57	} .	. .	0	{ 1	92	} 46 {	31	. .	4	114
		{ C. I.	6 to 36			318 43				{ 39	1 854		3 331	. .	32	64 to 73
21	Reading, Mass. . . .	C. I.	4 to 12	4 414	0	24 61	0	0	0	6	131	8	220	0	14	68 to 78
22	Springfield, Mass. . .	{ W. I., W. I. C. L., C. I. }	1 to 36	23 369	6 833	143 21	8 46	45	7 3	22	953	74	1 837	334	89	30 to 120
23	Taunton, Mass. . . .	C. I.	4 to 30	6 072	0	77 09	26 74	10	1 85	11	771	14	540	12	54	45 to 50
24	Troy, N. Y.	C. I.	4 to 30	4 827	965	61 36	1 86	17	0 53	1	783	16	1 348	0	38	9 to 107
25	Waltham, Mass. . .	C. I., W. I., C. L.	2 to 24	548	. .	50	4 20	[1] 0 5	. .	6	325	7	650	. .	. .	58
26	Wellesley, Mass. . .	C. I.	4 to 12	3 336	0	29	0 78	[1] 0 2	0 50	8	257	5	202	9	4	70
27	Whitman, Mass. . .	C. L., C. I.	. .	1 020	. .	16 7	. .	. .	. .	1	148	1	86	. .	. .	. . .
28	Woonsocket, R. I. .	C. I.	4 to 20	2 607	. .	45 32	17 23	[1] 44	0	5	540	5	448	. .	15	50 to 120

[1] Per mile.

1899.—TABLE V.—DISTRIBUTION.—SERVICE PIPES.

Number.	Name of City or Town.	16 Service Pipe. Kind.	17 Service Pipe. Size. Inches.	18 Service Pipe. Extended. Feet.	19 Service Pipe. Discontinued. Feet.	20 Service Pipe. Total in Use. Miles.	21 Service Taps. Added.	22 Service Taps. Total in Use.	23 Average Length of Services. Feet.	24 Average Cost of Services.	25 Meters. Added.	26a Meters. Now in Use. Domestic.	26b Meters. Now in Use. Manufacturing.	27 Motors and Elevators. Added.	28 Motors and Elevators. Total in Use.
1	Atlantic City, N. J.	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	.	. .	.	.	. .
2	Attleboro, Mass.	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	64	852		.	2
3	Billerica, Mass.	C. L. W. I.	. .	3 705	. .	2 14	51	187	. .	. .	15	54		.	. .
4	Boston, Mass. { Cochituate	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	.	. .	.	.	. .
	{ Mystic	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	.	. .	.	.	. .
5	Brockton, Mass.	W. I., L. L., C. I.	¾ to 6	11 462	244	29 93	183	5 140	60 64	. .	213	4 136		.	. .
6	Burlington, Vt.	G. I., C. I., Lead.	½ to 6	2 717	224	17 4	90	3 292	28	$ 8 80	158	2 082	39	0	35
7	Concord, N. H.	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	.	. .	.	.	. .
8	Fall River, Mass.	Lead.	½ to 2	. .	. .	. .	207	6 783	. .	. .	235	6 363		.	. .
9	Fitchburg, Mass.	W. I., C. L., C. I.	¾ to 8	. .	. .	. .	94	4 359	. .	. .	127	2 304		5	89
10	Holyoke, Mass.	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	.	. .	.	.	. .
11	Keene, N. H.	W. I., C. L., G., Lead.	¾ to 6	1 100	0	9 64	44	1 697	. .	. .	7	94		1	10
12	Lowell, Mass.	. . .	. .	. .	. .	78 3	167	10 529	. .	. .	413	5 268		.	. .
13	Lynn, Mass.	. . .	. .	. .	. .	. .	. . .	. . .	. .	. .	.	. .	.	.	. .
14	Middleboro, Mass.	W. I. C. L., Lead.	¾ to 3	2 638	. .	9 0	26	791	101 5	. .	23	332		1	7
15	New Bedford, Mass.	Lead, C. I.	½ to 10	6 389	389	59 93	144	9 151	44	24 82	364	1 035	59	.	99
16	New London, Conn.	W. I., C. L., G., C. I., Lead.	½ to 4	1 643	101	10 9	99	2 991	15 6	11 19	17	225		0	17
17	Newton, Mass.	Lead, W. I., C. I.	½ to 6	17 500	5 500	77 8	174	6 945	59	22 60	368	5 747	25	0	17
18	Oberlin, Ohio	G. I., Lead.	¾ to 2	. .	. .	. .	31	596	25	8 00	47	300	5	0	0
19	Plymouth, Mass.	Lead, C. L.	½ to 1	817	. .	5 85	77	1 832	17	5 92	.	. .	.	0	1
20	Providence, R. I.	Lead, C. I.	½ to 10	. .	. .	. .	606	21 020	. .	. .	376	17 124		8	151
21	Reading, Mass.	G. I., C. L., I., L. L. I., C. I.	¾ to 6	9 850	293	13 43	90	1 018	106 16	37 20	66	917		0	2
22	Springfield, Mass.	W. I. (Tarred & Galv.), C. I.	½ to 6	. .	. .	. .	386	9 456	. .	. .	171	2 898		24	226
23	Taunton, Mass.	C. L. W. I., T. L. W. I.	¾ to 3	7 106	6 179	42 33	155	4 372	. .	26 51	110	1 572	161	2	16
24	Troy, N. Y.	Lead, C. I.	¾ to 6	. .	. .	. .	104	7 413	35	25 00	21	309		.	. .
25	Waltham, Mass.	C. I., W. I. C. L.	¾ to 10	6 074	403	38	71	3 225	85	21 98	6	78		0	6
26	Wellesley, Mass.	C. I., W. I. C. L., I.	½ to 6	4 568	. .	14 5	41	836	114	14 99	30	763	5	0	2
27	Whitman, Mass.	. . .	. .	. .	. .	. .	40	965	. .	. .	.	450		.	. .
28	Woonsocket, R. I.	Lead, Iron.	⅝ to 6	1 305	0	6 16	98	2 108	13 29	12 48	60	1 777	61	0	12

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ELIMINATING THE CONFLAGRATION HAZARD.

BY EVERETT U. CROSBY, SECRETARY NATIONAL FIRE PROTECTION ASSOCIATION, NEW YORK CITY.

[*Read March 14, 1900.*]

Mr. President and Gentlemen, — The subject noted on your program as assigned to me, "Fire Protection Afforded by Water Works," is a considerable one. The brief space of this paper is devoted to but a portion of the subject, yet one which is of the greatest importance; namely, the elimination of conflagrations in cities by the universal installation of automatic sprinkler systems which must obtain their chief supply from the public water-works system.

Conditions which allow a spread of fire from building to building exist in every city, town, and village of this country, and are responsible for a considerable part of the annual fire waste, amounting last year to over $150 000 000.

Such extensive fires are a drain upon the resources of the people, paralyze business locally, and to the insurance companies bring enormous and unusual loss, which it is impossible for them to accurately measure in the rate, that the burden of the insurance tax may be equitably distributed.

There is no question but what city buildings must adjoin or be in close proximity, must have numerous windows in walls and skylights in roofs, and a majority of them must contain inflammable contents to a greater or less degree. The danger is enhanced as the buildings grow in height, the congestion of values increasing with each added story, as well as the inability of the fire department to reach all parts of the building with their hose streams. Eight-story buildings and

"four-story fire departments" are frequently found in the same city. It should be realized that such portions of buildings as are beyond the reach of hose streams may be quite as much without fire protection as though located in the backwoods. Again, buildings have increased very much in area; many of them, located within the hearts of cities, being of enormous expanse, and, perhaps the worst feature of all, with their numerous floors punctured at short intervals by unenclosed light, air and elevator shafts and stairways, thus allowing a fire to quickly spread from floor to floor. Such are most of the department stores, and many other retail and wholesale establishments, and they are properly termed "conflagration breeders."

Imagine a department store crowded from basement to sixth floor with an open stock of inflammable merchandise. Allow a fire to start therein, perhaps at a light-well in the center of a large area floor, and at a distance from the street, whence the fire department streams will not penetrate. Unless extinguished at the very start, that building is doomed, and nothing but your reservoir upset upon it would avail. There will even be cause for thanksgiving if the fire does not extend to other parts of the city.

Certain barriers to the extension of fires do exist. Many fire departments are as efficient as they could well be made. They are a necessity and always will be, but experience has already shown their limitations. They are powerless with conflagrations, and in many cases a difference of one to five minutes in the time of their arrival determines whether or not the building and contents are a total loss.

The fact that a conflagration is not an annual occurrence in each city has caused the public to overlook the great waste caused by these spreading fires or to forget it shortly after having been singed. Yet yearly, millions upon millions of values are annihilated in buildings other than those in which the fires originate.

But a reforming influence is now appearing. This country's era of extravagance is passing. The merchant who in the past little thought what his insurance cost, and could be burned out and again resume business without great loss of trade, now scrutinizes every item of expense and dreads an interruption of business which will deflect his customers to competitors. Attention is therefore directed to a reduction of the fire cost in cities. "Fireproof" buildings, so called, have been erected, only to find that even the best types are not fireproof so long as they contain combustible contents,

or are exposed by combustible buildings and inflammable stocks. Furthermore, it would be impracticable, within our day and generation, to tear down a city and replace it with these so-called "fire-proof" structures. Neither can we do away with their combustible contents. So we would be quite at a loss were it not for another factor which is on the increase each year, namely, *The Automatic Sprinkler System.*

This type of protection has been developed during the last twenty years. It was first applied to mills and workshops, and almost all such properties of prominence are now so protected. These are mostly isolated risks and alone receive the benefits of such protection; but when a system is installed in a city, every property in the conflagration district profits.

Yet the reverse is true, and a sprinklered city risk is still quite insecure so long as exposed by unsprinklered neighbors, for the exposure in burning will likely open the sprinklers on all floors of the equipped building, thus overtaxing any water supplies and pipe sizes which it is feasible to provide. Yet such an equipment has already in several instances — notably the Brown-Durrell fire in this city — retarded a spreading fire sufficiently to prevent a conflagration, although the building itself suffered practically a total destruction.

It is not my intention here to advocate the automatic protection of individual city risks, which is already a well-established custom, but to point out the great saving in fire cost, and the feasibility of the automatic sprinkler protection of *all* the buildings in the congested districts of cities; in other words, the practical *elimination of the conflagration hazard.* It is possible that underwriters may be able to hasten this work by allowing a special rate reduction upon a block when all the buildings therein are sprinklered.

Automatic sprinklers afford the chief means of private fire protection, and possess a prompt penetrating power not obtainable by any other known means. They act *instantly*, long before any alarm could be given at the public fire box; *locally* at the seat of fire, not being blinded by smoke into discharging large quantities of water where it is not needed; and *forcibly* when properly installed and fed by water under heavy pressure, filling the space with an irresistible deluge which not only quells the fire, but blankets the smoke, which would otherwise drift through the building, accomplishing an uncertain damage, impeding the exit of the inmates, and the subsequent

duties of watchman or fireman. This cannot be done by hose-stream service, and it is time the fact was realized. Of late, it has been emphasized almost weekly by the fires in Philadelphia and Newark.

Already property owners in large numbers have installed sprinklers. Their buildings are dotted here and there all over the city maps. What is needed now is the filling in of the intermediate spaces. Shortly the community will call for it. If three fourths of the buildings in a block are equipped, the portion not protected will be considered as a public menace, and public statutes may properly compel its equipment. Already they dictate as to the storage of oils and other extra inflammable substances, regulate construction, and compel the maintenance of standpipes, hose, fire escapes, etc. Doubtless, the landlord will in time consider the sprinkler system just as necessary a part of his fittings as the heating or lighting systems, and the municipality will have a corps of inspectors to see that the protection is not impaired.

Now all this means many, many more connections from the water-works systems, which is where your interests and those of the Fire Protection Engineer come together. This "coming together" should be a happy union of effort, not a collision, and I surely voice the wish of my associates in indicating our desire so to make it. Surely a great responsibility rests upon the water department in providing and maintaining an adequate service.

The public looks to the underwriter for the sprinkler specifications, and the latter looks to the city water-works system as, in most cases, the best possible source of water supply.

Very properly it is your duty to be informed as to the use of the connection, to avoid undesirable features, and, all being satisfactory, to provide the supply for the fire equipment. In past years there has been much abuse in the use of a water-works connection. But times have changed. The day of lax specifications and inspection is passing. We must rely to a considerable extent upon the service received from the water-works system, making much dependence upon private water supplies only when the public system lacks in pressure, volume, or quality.

As to quality, we have little to fear in New England, but in some other parts of the country, mud, eels, etc., are very serious obstructions to the smaller sprinkler pipes and to the sprinkler heads themselves. Neither is the lack of volume so much to be feared in the central city districts, but the pressure is often found wanting. This is partly

due to the increasing height of buildings. It is a fact, often overlooked, that sprinklers need a high pressure maintained upon such heads as may have opened in order to accomplish that which is expected of them. Seventy-five pounds is ideal, and the pressure is considered inadequate if less than twenty-five pounds at the sprinklers in the upper story.

Naturally, we have to take the public pressure as we find it, and when it is deficient, there are three types of private water supply commonly specified,—pressure tanks, pumps, and connecting pipes for attachment from the public fire engines. The pressure tanks are very simple; nothing more than boiler shells located upon the upper floor or roof, filled two thirds with water and the remainder with air compressed at seventy-five to one hundred pounds, which will expel all the water, the last leaving the tank at fifteen to twenty-five pounds pressure.

As these tanks can be filled with water from the public system, cleaned out and inspected as frequently as you like, you could have no objection to their connection to a sprinkler system which was also fed by the public water works. You object to a similar connection from a pump, draughting from some uncertain and perhaps foul source of supply which may, by the leakage of the check valve in the street connection, discharge its contents back into the street main, thus polluting the public water supply. We must admit the argument at once, and should be able to furnish a cement-lined reservoir or wooden tank, filled by city water, and cleaned out periodically, from which the pump shall draught.

In the past, varying insurance regulations governing automatic sprinkler equipments were issued, but in 1896 the National Fire Protection Association, composed of the various boards and bureaus in this country and Canada, formulated uniform regulations governing the installation of automatic sprinklers, which are now in general use throughout the land. They are presented as an appendix to this paper.

The rule that a sprinkler orifice shall be designed to discharge approximately twelve gallons per minute under five pounds pressure is the basis upon which the entire regulations are framed. This means a discharge under higher pressures approximately as follows: 10 pounds, 17½ gallons; 15 pounds, 21½ gallons; 20 pounds, 25 gallons; 30 pounds, 30 gallons; 40 pounds, 35 gallons; 50 pounds, 40 gallons; 75 pounds, 50 gallons; 100 pounds, 58 gallons.

As the equipments are, under average conditions, expected to allow the opening of, and proper supply of water to, at least forty sprinklers in any one fire, you will see that a considerable consumption of water may result. A system installed under these rules never fails except when the water for such a discharge is not forthcoming, due to weak water supplies, closed valves, or obstructed pipes; or when too great a number of heads is opened, due to quick-spreading fires as a result of explosive or highly inflammable contents, draughts from vertical openings, blower systems, etc., or when the contents are piled so as to prevent a proper water discharge. The better supplied systems can discharge under sufficient pressure for efficient spray service at least a thousand gallons per minute, the equivalent of four standard hose streams.

These national regulations do away with individual fads and fancies, and place before you and the property owners in black and white just what is, and is not, desired.

We have alluded to the sprinkler orifice, quantities of water discharged per minute, the desire for a water-works connection, and the use of pressure tanks, pumps, and steamer connections. The rules are ample and would serve as the text for a very long sermon, but I will allude to but one more point which may be of special interest to you.

We intend to prohibit the use of sprinkler piping for anything but fire service. Circulation in same means the presence of objectionable sediment. Let the interior hose and domestic pipes be on a separate metered connection.

The use of a proper alarm valve on each sprinkler system will be a positive check upon any circulation. Such a valve will eventually be considered a necessary part of every system.

It has been my purpose to-day to call your attention to the extensive use of automatic sprinkler systems, and the probability of their still more general adoption in the future; to state our appreciation of the great value in a water-works connection and our intention to have it properly used; and finally to indicate the uniform rules now in force governing this subject, which can be referred to in detail to fully understand this method of applying water upon fires, a method which must be chiefly relied upon for the prevention of serious city conflagrations.

The general principle underlying automatic sprinkler protection is well understood and appreciated by firemen and all who have made a

general study of extinguishing fires; namely, the application of water directly to the fire in its first or incipient stage. Automatic sprinklers properly installed are in every closet, under every stairs, in the center of all large stores as well as front and rear, in every portion of the building, ready night and day without the intervention of human agencies to distribute the water directly on the fire and in its early stages when it can be controlled. The great value of water-works connections in supplying water to sprinkler systems is understood and appreciated, and we need your assistance and advice in our efforts to bring into more general use the application of this most important and necessary means of protection against conflagration hazards in the congested districts of our large cities and towns.

I beg to express my appreciation of the honor conferred in the invitation to address you at this time and on this subject. I hope it may be the commencement of mutual conference and mutual assistance between your valuable organization and underwriting associations.

APPENDIX.

Abstract of Automatic Sprinkler Regulations.

A. PRELIMINARY INFORMATION.

1. Many buildings require preparation for sprinkler equipment. All needless ceiling sheathing, hollow siding, tops of high shelving, needless partitions or decks should be removed. Necessary "stops" to check draught, necessary new partitions, closets, decks, etc., should be put in place that the equipment may conform to same.

2. Full effective action of sprinklers requires about 24 inches wholly clear space below roofs or ceilings; this loss of storage capacity should be realized in advance of equipment.

3. Sprinkler equipments require accessory woodwork, dry-pipe valve closets, ladders, anti-freezing boxing for tank pipes, etc. This work should be promptly attended if not let with sprinkler contract.

4. Sprinkler installation is a trade in itself. Insurance inspectors cannot successfully act as working superintendents nor correct errors of beginners. It is strongly recommended to entrust sprinkler work to none but fully experienced and responsible parties.

5. Experience teaches that sprinklers are ofttimes necessary where seemingly least needed. Their protection is required not alone where a fire may begin but also wherever any fire might extend, including wet or damp locations.

6. A maximum protection must not be expected where sprinklers are at more or less permanent disadvantage, as in the case of stocks very susceptible to smoke and water damage, buildings having deep piles of hollow goods, excessive draughts, explosion hazards, or large amounts of benzine or similar fluid.

7. Paper or similar light inflammable ceiling sheathing is objectionable and unnecessary. Where floors leak dirt, an acceptable sheathing may be made of lath and plaster, matched boards or joined metal. All channels back of sheathing to be thoroughly closed between timbers or joists. Sheathing to be tightly put together and kept in repair. In mill bays, sheathing to follow contour of timbers without concealed space.

8. Vertical draughts through buildings are detrimental to the proper action of sprinklers, and must be "stopped" where practicable.

9. Sprinklers cannot be expected to keep out fire originating in unsprinkled territory. Stringent measures should be used to cut off all unsprinkled portions of buildings or exposures.

B. THE AUTOMATIC SPRINKLER.

These rules (Sec. B) are but a partial outline of requirements. An automatic sprinkler which will meet these requirements and no more will by no means be necessarily acceptable.

1. As a basis for these rules, it is required that each automatic sprinkler have an unobstructed outlet of such size and form that with 5 pounds pressure maintained at the sprinkler, it will discharge approximately 12 gallons per minute.
2. An automatic sprinkler upon original test must not leak under a pressure of 300 pounds hydraulic pressure.
3. Sprinklers upon original test must not burst or leak by suddenly increasing the pressure from 0 to 300 pounds, repeated 500 or more times.
4. An automatic sprinkler when intended for ordinary use must, when immersed in hot fluid, fuse at not less than 155 degrees F. nor more than 165 degrees F. Head not to be under pressure in this test. "Hard heads" in like manner must fuse at not less than 275 degrees or more than 300 degrees F. The fusing point of solder should not change with age.
5. On original test an automatic sprinkler on fusing must open without perceptible halt or hesitation at any point of the opening action, all freed parts must throw clear. This test to be made without subjecting the sprinkler to pressure or depending upon the action of a coil spring.
6. An automatic sprinkler must be designed to open and spray satisfactorily in an upright or pendent position.

7. Rules for Distribution of Water from Sprinklers.

Sprinkler upright or pendent, with deflector 4 or 6 inches below smooth ceiling and 10 feet above smooth floor, —

Shall, under 5 pounds nozzle pressure, wet ceiling over an area of not less than 3 to 4 feet in diameter.

Shall, when under 5 pounds nozzle pressure, throw approximately 90 per cent. of water inside an area 10 feet square on floor.

Shall, when under 50 pounds pressure, throw not less than 75 per cent. of water inside the 10 feet square area.

Distribution in both above tests to be approximately uniform over the 10 feet square area.

Water should not be cut up into fine spray.

Rotary deflectors are allowable, but the distribution must be satisfactory with deflector fixed.

The distribution in any direction shall not be obstructed by yoke, levers, or other parts of sprinkler.

8. Automatic sprinklers must contain no iron, steel, or fibrous material subject to the effect of corrosion.

C. LOCATION AND ARRANGEMENT OF AUTOMATIC SPRINKLERS.

1. Sprinklers to be located in an upright position. (*Note.* — Where construction or occupancy of a room makes it preferable, permission may be given, except on dry pipe systems, to locate sprinklers in a pendent position.)
2. Sprinkler deflectors to be parallel to ceilings, roofs, or the incline of stairs, except that the deflectors of sprinklers in the peak of a pitch roof shall be horizontal.
3. Distance of deflectors from ceilings or bottom of joists to be not less than 3 inches nor more than 10 inches.
4. Sprinklers to be placed throughout premises including basements and lofts, under stairs and inside elevator wells, belt, cable, pipe, gear, and pulley boxes, inside small enclosures such as drying and heating boxes, tenter and dry room enclosures, chutes, conveyor trunks and all cupboards and closets except they have tops entirely open and so located that sprinklers can properly spray therein. Sprinklers not to be omitted in any room because it is damp or wet.

Special instructions must be obtained relative to placing sprinklers inside boxed machines, metal air ducts, ventilators and concealed spaces, and under large shelves, benches, tables, overhead storage racks, platforms and similar watersheds.

5. In vertical shafts having inflammable sides, a sprinkler to be provided for each 200 square feet of the inflammable surface.

Metal lined shafts are construed as inflammable.

Such sprinklers to be installed at each floor when practicable and always when shaft is trapped.

D. SPACING OF AUTOMATIC SPRINKLERS.

(Also see F, 4.)

1. The distance from wall or partition must not exceed one half the distance between sprinklers in the same direction.
2. A line of sprinklers should be run on each side of a partition. Cutting holes through a partition to allow sprinklers on one side thereof to distribute water to the other side is not effectual. This rule applies to solid or slatted partitions.

3. Under mill ceiling (smooth solid plank and timber construction, 6 to 12 feet bays) one line of sprinklers should be placed in center of each bay and distance between the sprinklers on each line not to exceed the following: —

- 8 feet in 12 feet bays (measuring center to center of timbers).
- 9 feet in 11 feet bays (measuring center to center of timbers).
- 10 feet in 6 to 10 feet bays (measuring center to center of timbers).

4. Under joist ceiling, open finished, distance between sprinklers not to exceed 8 feet at right angles with joists or 10 feet parallel with joists. (*Exception.* — An exception may be made to this rule *if the conditions warrant*, namely, *special permission* may be given to install but one line of sprinklers in bays 10 to 11½ feet wide from center to center of the timbers which support the joists. In all cases where such bays are over 11½ feet wide, two or more lines of sprinklers must be installed *in each bay* as required by the rules for spacing. This does not apply where beams are flush with the joists, in which case sprinklers may be spaced as called for in rule D, 4.

5. Under a pitch roof sloping more steeply than 1 foot in 4, one line of sprinklers to be located in peak of roof, and sprinklers on either side to be spaced according to above requirements. Distance between sprinklers to be measured on a line parallel with roof.

6. Under open finish, joisted construction floors, decks, and roofs, the sprinklers shall be "staggered" spaced so that heads will be opposite a point halfway between sprinklers on adjacent lines, the end heads on alternate lines to be within 3 feet from sides of room. (*Note.* — This regulation applies to all sprinklers under open finished joists not excepting the sprinklers within a bay whether on one, two, or more lines; where the joists are flush with timbers; or where the channel ways between joists are "stopped" at intervals. Care must be taken that the end and intermediate sprinklers do not violate the rules for joist work spacing.)

7. Special instructions must be received relative to location of sprinklers under floors and roofs of unusual construction which would interfere with distribution of water and for which provision is not hereinbefore made.

E. PIPE SIZES FOR AUTOMATIC SPRINKLERS.

1. In no case shall the number of sprinklers on a given size pipe exceed the following:

Size of Pipe.	Maximum No. of Sprinklers Allowed.
¾-inch,	1 sprinkler.
1 ,,	2 sprinklers.
1¼ ,,	4 ,,
1½ ,,	8 ,,
2 ,,	16 ,,
2½ ,,	28 ,,
3 ,,	48 ,,
3½ ,,	78 ,,
4 ,,	110 ,,
5 ,,	150 ,,
6 ,,	200 ,,

2. If more than 6 sprinklers be placed on a "branch line" of pipe, the following schedule shall apply: —

Size of Pipe.	Maximum No. of Sprinklers Allowed.
¾-inch,	1 sprinkler.
1 ,,	2 sprinklers.
1¼ ,,	4 ,,
1½ ,,	6 ,,
2 ,,	8 ,,
2½ ,,	16 ,,
3 ,,	28 ,,

Furthermore, no feeder to any such "branch line" shall be smaller than said "branch line." (*Note.* — The old-fashioned "Parmelee" or "tree" arrangement of piping, namely, a pipe with short branches to one sprinkler on either side, shall be construed as coming under this rule.)

F. FEED MAINS AND RISERS.

1. "Center central" or "side central" feed to sprinklers is recommended. The former preferred, especially where there are over 6 sprinklers on a branch line. End feed is not approved.

2. There should be a separate riser in each building and in each section of a building divided by fire walls. The size of each riser to be sufficient to supply all the sprinklers on any one floor, as determined by the standard schedule of pipe sizes. If the conditions warrant, special permission will be granted allowing the sprinklers in a fire section of small area (total number of sprinklers not to exceed 48 per floor) to be fed from the riser in another section.

3. Where there are sprinklers enough in one room to require a 6-inch riser, according to schedule, it is preferable to have these sprinklers supplied through two or more smaller risers.

4. Where two or more floors communicate by openings not provided with approved "stops," acceptable "curtain boards" must be fitted around the openings at each floor; or, by consent of Board having jurisdiction, the automatic sprinklers at each floor may be placed within one foot of the openings.

(Sketches of piping plans omitted.)

G. VALVES AND FITTINGS.

1. Pipes must be supported in a substantial manner by wrought or cast iron hangers well secured.
2. Long bend fittings are recommended.
3. On wet systems, there shall be a test pipe ½ inch in diameter connected directly with each riser in upper story and arranged to discharge outside building.
4. There shall be a straightway gate valve and a straightway check valve in the pipe connecting each water supply with sprinkler system. Straightway check valves to be placed in horizontal pipe, or in vertical pipe "looking up," never "looking down."
5. All gate valves (except they are fitted with post indicators) in supply pipes to sprinklers, in discharge pipes from tanks, in suction and discharge pipes from pumps, to be of outside screw and yoke or approved sign indicator pattern, and to be kept secured open with padlocked or riveted leather straps passing around the riser and spoke of the wheel. Draw-off valves to be secured closed. Cases about post gate valves to be arranged to drain through at least a ¾-inch outlet having a non-corrosive bushing.
6. Drip pipes to be provided to drain all parts of system. Drip pipes at main risers to be not smaller than 2 inches.
7. Main discharge pipes from gravity and pressure tanks, as well as from water-works systems and pumps, to connect with sprinkler system at foot of riser. Locate in this lower level the check valve in each connecting pipe, also one gate valve controlling all water supply to sprinklers. Place the gate valve called for in each connecting pipe close to the supply, as at the tank, pump, or in connecting pipe to riser from water-works system.
8. Where sprinklers are supplied from yard main, if possible, place an outside post indicator gate valve in connecting pipe at safe distance from building (say 40 feet).
9. When a pump, not located in a non-combustible pump house, discharges into a yard main fed by another supply, a check valve or post gate valve shall be placed in this discharge pipe outside the building underground.
10. Each underground check valve to be located in a pit accessible through manhole. Pit to be tight enough to keep out water from the ground or surface, and to be provided with a deck forming a double air space, to prevent freezing.
11. A standard make, 5-inch dial, spring pressure gage to be connected with the discharge pipe from each water supply (this includes the connecting pipe from public water works); also with each sprinkler system above the alarm check or dry valve; also at air pump supplying pressure tank, at pressure tank, and in each independent pipe from air supply to dry systems. Gages to be located in a suitable place, and where water will not freeze. Each to be controlled by a cock valve having a square head for wrench. A plugged tee or pet cock to be located between each cock and gage.

H. ALARM VALVE SYSTEM.

1. Every automatic sprinkler system should contain an alarm valve so constructed that a flow of water through same would operate an electric gong, a mechanical gong, or both, as the character of the property and circumstances may require. In cities where there is a thermostat alarm company with a central station, the alarm valve may be connected with such central station. In other places, especially in small towns, the valve may be directly connected with public fire department house or some other suitable place.

The use of both electric and mechanical gongs is strongly recommended. The gong of the latter can be located on the outside of building or any other desirable place on the premises. Valve should be so constructed that the flow of water through but one sprinkler would cause it to operate. It must not be affected by the varying water pressures received from street mains or automatic pumps. It must have a water way equal to or greater than the pipe in which it is installed and must be so designed as to but little diminish the flow of water. Valve to be so located that the passing of water through any of the sources of supply to any of the sprinklers will cause its action. To accomplish this in some equipments, it would be necessary to use two or more alarm valves. Construction of valve to be such that it cannot be prevented from opening in full by water column, corrosion, sticking of parts, or sediment. No valve to be installed unless it has the approval of the underwriters having jurisdiction.

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J. WATER SUPPLIES.

1. *Double Supply.*—Two independent water supplies are absolutely essential for the best equipment. At least one of the supplies to be automatic and one to be capable of furnishing water under heavy pressure. The following are acceptable supplies: Public

water-works system, duplex steam pump, private reservoir or standpipe, gravity tank, air pressure tank, rotary pump. The choice of water supplies for each equipment to be determined by the underwriters having jurisdiction.

2. No water supply for sprinklers to pass through a meter or pressure regulating valve, except by special consent.

3. Connection from water supply or main pipe system to sprinkler riser to be equal to or larger in size than the riser, and to supply no hydrant or standpipe.

K. PUBLIC WATER-WORKS SYSTEM.

(Rules also applicable to private reservoir and standpipe systems.)

1. Should give not less than 25 pounds static pressure at all hours of the day at highest line of sprinklers.

2. Street main should be of ample size, in no case smaller than 6 inches.

3. If possible, avoid a dead end in street main by arranging main to be fed at both ends.

L. STEAM PUMP.

1. Steam pump to be of approved duplex type (underwriters' pattern preferred), of the capacity named by the underwriters in each instance, but never less than 500 gallons rated capacity per minute, so located on the premises as to be free from damage by fire or other causes, and to take water from an approved source having a sufficient quantity of water to supply the pump while delivering its rated capacity for at least sixty minutes. Suction pipe to have a strainer, and, if the lift be more than 5 feet, a foot valve may be recommended. If pump is to be a supply for hose or open sprinklers, as well as automatic sprinkler system, it should never be of less than 750 gallons rated capacity. (*Note 1.* — In determining the rated capacity of a pump, 70 revolutions shall be allowed for 12-inch stroke, 75 revolutions for 10-inch stroke. Ten per cent. shall be deducted for slip.) (*Note 2.* — It is requested that a clean and well-floored room with a tight roof be provided for fire pump. No room is acceptable where the conditions prevent or discourage the engineer from keeping pump in good condition.)

2. Where a pump does not take water under a head, it should be primed from water tank, used exclusively for that purpose, of not less than 200 gallons capacity or its equivalent. Priming pipe to connect into each of the four water chambers.

3. Pump to be so located in respect to its water supply that at no time shall it have a lift of over 15 feet during sixty minutes discharge at rated capacity. (*Note.* — When a pump takes water under head, there shall be a gate valve in suction pipe, located at pump.)

4. Discharge pipe to contain a spring relief valve and pressure gage.

5. Two and one-half inch hose connections with gate valves to be placed in pump discharge, at pump (one connection for every 250 gallons rated capacity of pump). These are required for the purpose of properly testing pump.

6. If an automatic regulator is placed in steam connection to pump, it shall be on a by-pass with a shut-off valve on each side of same and a satisfactory steam trap provided.

7. Steam pressure of not less than 50 pounds to be maintained at all times. Provision to be made for sufficient steam power to run pump to full rated capacity; not less than 40 horse-power for each 250 gallons rated capacity of pump. Means shall be provided for liberally oiling steam chests of pumps independent of sight feed, namely, hand oil pump. Three gallons special quality oil to be kept at pump for this purpose.

8. Where a steam pump is the primary supply an automatic gage to record the steam pressure in pump steam chest shall be applied.

9. Fire pump to be operated at least once a week.

10. Any boiler house on which pump depends for steam supply should be of brick or stone, detached or cut off from main buildings by standard fire doors.

11. Steam pipe from boiler or boilers to pump to supply pump only; as far as practicable to be located where not subject to injury in case of fire or other accident, to be fitted with steam trap and drip pipe. Where there is more than one boiler, the arrangement of pipes and valves to be such that each boiler may be "cut out" without interrupting steam supply to pump from the other boilers. Where there are several fire pumps, each should be arranged to be "cut out" without affecting the others. Pump exhaust to be free from liability to back pressure.

12. Valves to be located in boiler house so that all steam supply to other buildings may be cut off from them in time of fire and reserved for pump.

M. GRAVITY TANK.

1. Elevation of bottom of tank above highest line of sprinklers on system which it supplies and capacity of tank to be specified by the underwriters having jurisdiction. In no case shall a tank of less than 5 000 gallons capacity be accepted. The greater the elevation of a gravity tank, the less likelihood of inefficient service. Underwriters having jurisdiction are urged to have such tanks placed at the greatest practicable elevation.

2. Water for filling tank shall be conveyed through fixed iron piping not less than 1¼ inches in size. Sprinkler piping not to be used for this purpose.

3. Tank to be used as a supply to automatic sprinkler system only, except that, at the discretion of the underwriters, tank may be made larger than called for, and so arranged that the excess supply only may be used for domestic service.

4. *Tell-tale.*—All gravity tanks to be provided with a water level indicating device satisfactory to the underwriters having jurisdiction.

5. End of sprinkler riser should enter bottom of tank and project above bottom 4 inches, to avoid sediment entering pipe system.

6. Provision shall be made to drain each tank independent of the sprinkler system.

7. Provision must be made to prevent water from freezing in tank and pipes communicating with the same. A tank exposed to the weather must have a double cover, provided with trap door. When a steam pipe is used for heating tank, it should be run directly from boilers with controlling valve located in boiler room. A check valve to be located in this pipe at tank to prevent siphoning.

8. A permanent substantial ladder extending 3 feet above tank or satisfactory stairway must be maintained to allow access to tank on outside. Also a ladder to be permanently located inside tank. (*Note.*—The outside ladder at a tank exposed to the weather affords a treacherous foothold at best. For years after it is erected, it must be used by inspectors in all seasons and conditions of wind, temperature, and storm. A ladder of much more than ordinary strength and durability is required and must be most securely attached. A heavy iron pipe ladder, having diamond-shaped treads, is recommended.)

9. Tank to be built and supported under specifications and supervision of the municipal or building authorities.

N. PRESSURE TANK.

1. Total capacity of tank or tanks to be not less than 4 500 gallons except by special consent.

2. Tank not to be located below upper story of building. The two valves in water gage are ordinarily to be kept closed, and opened only to ascertain the amount of water in tank; as breaking of or leakage about glass would cause the escape of pressure.

3. Water for supplying tank to be conveyed through fixed iron piping not less than 1¼ inches in size. Sprinkler piping not to be used for this purpose. Pipe from air pump to tank to be not smaller than ¾ inch; to be independent of water supply pipe; to connect with tank above the water level. Both water and air connections to be fitted with check and stop valves located near tank.

4. Tank to be kept two thirds full of water, and an air pressure (not less than 75 pounds) maintained, such as will give not less than 15 pounds' pressure on highest line of sprinklers when all water has been discharged from tank.

5. Wherever steam is available, a steam-driven air compressor shall be used.

6. Tank to be used as a supply to *automatic* sprinklers and hand hose only. (See Rules S, 1 and 2.)

7. Provision shall be made to drain each tank independent of the sprinkler system.

8. It is desirable to have water fed to tank by a pump so that proper water level may be restored at any time without reducing air pressure.

9. Tank to be built and supported under specifications and supervision of the municipal or building authorities.

O. ROTARY PUMP.

1. To be of approved type, rated capacity never less than 500 gallons per minute; to have gears at both ends. To be located where easy of excess and free as possible from damage by fire. If inside main building, to be arranged, together with water wheel, to start from outside of building; to take water from a source having sufficient quantity of water to supply the rated capacity of the pump for sixty minutes.

2. In many cases it will be found necessary to provide an approved friction clutch by which shafting and machinery can be disconnected and full power confined to driving pump.

3. Pump to be so located in respect to its water supply that at no time shall it have a lift of over 10 feet during sixty minutes' discharge at rated capacity. To have hose connections, spring relief valve, gate in suction and pressure gage the same as steam pump. To be started by friction clutch or friction gearing. Care should be taken to provide sufficient power to run pump to full rated capacity.

4. Rust and usage will impair the efficiency of a rotary pump more quickly and to a much greater degree than an underwriter steam pump. In most cases, a rotary pump cannot be as advantageously located and is under less control. Consequently, it is not to be recommended when practicable to install a steam pump.

5. Means should be provided for liberally oiling journals. One barrel special quality oil to be kept at pump for this purpose.

P. STEAMER CONNECTION.

1. In addition to the above required double supply, it is recommended that a hose inlet pipe to sprinkler system be provided for connection from hose or steamer of public fire department, in all cases where the public water works is not sufficient to exert 25 pounds' pressure at highest sprinkler, or is not connected to the sprinklers.

Said pipe to be not less than 3 inches in size and fitted with a straightway check valve, but not with a gate valve. To be attached *above* dry valve or gate valve controlling sprinkler riser where there is but one riser and *below* said dry or gate valves where the equipment has more than one riser.

Hose connection to suit thread of public department.

Large buildings to have several connections designated by proper signs.

Q. UNDERGROUND PIPES AND FITTINGS.

Hydrant Mains.

1. No 4-inch pipe to be used.

2. For pipes extending to a dead end —

(*a*) Allow 200 feet 6-inch pipe with one 3-way hydrant.

(*b*) Allow 500 feet 6-inch pipe with one 2-way hydrant. (This might be extended in special cases.)

(*c*) Allow 1 000 feet 8-inch pipe with one 3-way hydrant.

(*d*) Allow 500 feet 8-inch pipe with one 4-way hydrant or its equivalent in hose streams.

(*e*) Allow 300 feet 8-inch pipe to first hydrant, where there is a hydrant equivalent of six streams.

(*f*) Whereas the above limitations for 8-inch pipe are low, it is deemed undesirable to have over four streams on a dead end, and loop system would ordinarily be employed where it is intended to concentrate over four streams at one point.

(*g*) Never allow more than four streams on 6-inch branch pipe.

3. For loop systems —

(*a*) With two 3-way hydrants, say 250 feet apart, allow 250 feet 6-inch pipe from each hydrant towards source (preferably use 8-inch pipe with 3-way hydrant systems).

(*b*) With two 2-way hydrants, say 250 feet apart, allow 500 feet 6-inch pipe from each hydrant towards source.

(*c*) With three 2-way hydrants 250 feet apart allow 250 feet 6-inch pipe from end hydrants towards source.

(*d*) To feed four 2-way hydrants or their equivalent, use 8-inch main feed pipes and allow 500 feet of 8-inch pipe each way from end hydrant to water supply, rest of pipe 6-inch, if desired.

(*e*) To feed five 2-way hydrants or their equivalent, use 8-inch main feed and allow 250 feet from end hydrants to water supply.

(*f*) Where water supplies are such that over four streams can be obtained, loop pipes should never be less than 8-inch.

(*g*) In laying out a loop system where it is intended to concentrate four to six streams at any one point, an 8-inch loop should be amply sufficient even if it is as much as 1 000 feet from supply to point of concentration.

(*h*) Under conditions where a large number of streams can be concentrated at one point, it would be sometimes desirable to use 10-inch or 12-inch pipe.

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S. MISCELLANEOUS RULES.

1. Circulation of water in sprinkler pipes is very objectional owing to greatly increased corrosion, deposit of sediment, and condensation drip from pipes; sprinkler pipes must not be used in any way for domestic service.

2. Hand hose to be used for fire purposes only may be attached to sprinkler pipes within a room under the following restrictions: Hose not to be larger than 1¼ inches. Nozzle not to be larger than ½ inch. Hose not to be connected to any sprinkler pipe smaller than 2½ inches, never to be attached to a dry pipe system.

T. CAUTIONS AND PROHIBITIONS.

1. Where pipes are painted or bronzed for appearance, the moving parts of sprinkler heads must not be so coated.

2. Sprinkler heads must be free to form an unbroken spray blanket for at least 2 feet under the ceiling from sprinkler to sprinkler and to sides of room. Any stock piles, racks, or other obstructions interfering with the foregoing are not permissible.

3. Where a building settles and deprives a dry pipe system of its drainage, the ends of lines must not be raised to violate Rule C, 3. The drainage should be restored by shortening the vertical piping.

4. Use of water or circulation of water above base of sprinkler riser is prohibited. (See Rules S, 1; M, 2; N, 3.)

5. Notice that it is the deflector of a sprinkler which must be at least 3 inches (and not over 10 inches) from ceiling or bottom of joists; 5 to 6 inches is the best distance with average pressure and present types of sprinklers. (See Rule C, 3.)

6. Sprinkler piping must not be used for the support of stock, clothing, etc.

7. It is not permitted to change, plug up, or remove the fittings pertaining to dry pipe valves, pressure tanks, pumps, gages, etc. If such fittings leak or become deranged, they are to be put in order.

8. There should be maintained on the premises a supply, never less than six, of extra sprinklers to promptly replace any fused by fire or in any way injured.

DISCUSSION.

PRESIDENT COOK.* Mr. Crosby's paper is now open for discussion. I may say, speaking from the standpoint of the water-works superintendent, that when we find a manufacturing concern is drawing water from the sprinkler system surreptitiously, it shakes our confidence in the sprinkler system and also in the man who is using it. My experience has been that the ordinary manufacturer, if he gets short of water, will go to the city supply. Now, what we want, and what Mr. Crosby suggests, is that we may be protected by the insurance people compelling every manufacturer to have nothing connected with the sprinkler pipes except the sprinklers themselves; and his suggestion of an automatic valve electrically connected, whereby in case of any draught through the check valve an alarm will be immediately rung, I think is a good one.

We must have some protection. Only this last week I went into a manufacturing establishment in my city and found that for ten days they had been using water through their fire supply to feed their boilers. Their pump supply from the river had got clogged up; but during the manipulation of the valves to feed their boilers through the heater the fireman got mixed up in some way, so they could n't supply the boilers at all, and had to shut the mill down. They telephoned to the water office and wanted to know if we had shut the water off; their consciences began to trouble them. I went over there and soon remedied the trouble. Now we have a meter on the fire pipe. If the insurance people will insist that no connection shall be made from the fire pipes except for sprinkler purposes, it will surely help us a great deal.

MR. EDWIN C. BROOKS.† I fully agree with Mr. Crosby as to the desirability of the adoption of some regulation in regard to the introduction of fire supplies that would meet the approval of both the insurance companies and the water-works authorities.

I find that plans are made for the introduction of a supply of water to fire pumps without the least regard to the city supply in case of accident, or failure of some one to do what was expected to be done in case of fire, or through the failure of some check valve to operate as was intended. The whole idea seems to be the protection of the property in question. An auxiliary supply for fire pumps is, no

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* Superintendent, Woonsocket Water Works.
† Superintendent, Cambridge Water Works.

doubt, in many cases necessary, and I think no one should object to such an arrangement, provided, of course, that the supply is equal in purity and fitness for domestic use to that of the city, and is kept so.

Mr. Morris Knowles.* There are two questions I would like very much to ask Mr. Crosby. One is, does he know of any place where this automatic electric alarm valve has been used, and with what success; the other is, after a new plant has been equipped for a fire service, thoroughly in accordance with the ideas of the underwriters, with no connection whatever except for fire sprinklers, have they any penalty which they inflict upon the insured if any connection shall be made afterwards, or do they do anything to prevent it? Do they have inspectors, for example, who go around and inspect all the piping, and who will prevent anything of that sort?

Mr. Crosby. Replying to the first question, Mr. President, there is an alarm valve now in service called the English alarm valve. It is the only one generally in use in New England, and has been employed for some seven or eight years, and with a very fair degree of success. I think I am safe in saying that from seventy-five to eighty-five per cent. of the equipments in the central business section in Boston are fitted with these alarm valves. They are connected electrically with the central station of the thermostat company, which is the automatic fire alarm company, and upon any movement of water in the pipe the valve must open, the electric connection is made, and it will ring an alarm at the central station, giving notice either of a fire or of leakage. The system has met with very excellent success in Boston, but of course it is under the best conditions here, there being this large central station where there are people who can within a couple of hours remedy any defect, and who test the circuits out every day.

There are a number of reasons for installing that valve. We find that the property owner, as a rule, is very anxious to put it in. He is covered under his fire policy for any damage which may result if a sprinkler opens in case of fire and discharges water through the building, damaging the stock on the lower floors; but in case he leaves a window open at night, forgetting to close it, and the water in a sprinkler freezes and bursts the head, allowing the water to run down through the building during the night, he has to stand the loss himself. Now, by having such a valve in he is not only doing

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*Civil Engineer; Water Commissioner, Lawrence, Mass.

something which helps the insurance companies, for which he gets an allowance in the rate, but he is also protecting himself to a large degree against water damage due to a broken pipe or sprinkler.

Now, as to the second point, that of inspection. All of the sprinklered risks which get the sprinkler allowance are inspected from once in six weeks to once in three months by the insurance authorities. It is a part of the inspector's duty to find out if the system is being used for anything but fire purposes. We have found that when a circulation is maintained in the pipes they are being re-charged every minute or every hour with a new supply of water, bringing in its own percentage of sediment which will settle in the fittings, sprinkler heads and tees, resulting in clogging up the pipes, very much to the detriment of the interest of the insurance companies; so we are looking out for that. Where the alarm valve is in use they simply cannot maintain a circulation, because the alarm would be ringing all the time. And, as I said in my previous remarks, we should look to the general introduction of that alarm valve in the future as one of the best safeguards against using a sprinkler system for anything but fire purposes.

Mr. Knowles. Is this alarm valve always closed?

Mr. Crosby. The alarm valve is always closed. The one to which I have referred is nothing more than a vertical check valve. The disc rests on a seat ring which is channeled, the channel being covered and closed by the disc when the disc is seated. Out of that annular seat ring is conducted a small pipe which connects with a diaphragm circuit-closer, or with a water rotary mechanical gong. The minute there is a flow of water in the pipes the disc rises, allowing the water to flow into the seat ring channel and a pressure to be established, by the water running out in the short length of pipe, and operating the electric circuit-closer or ringing the mechanical gong, as the case may be. We like very much to have both, because it makes two strings to the bow, one electrical and one mechanical, and with less chance of a failure.

Mr. John C. Chase.* I would like to ask Mr. Crosby if these establishments he speaks of in and about Boston, which have been equipped in this way, are mercantile or manufacturing establishments?

Mr. Crosby. They are largely mercantile. Those to which I have been referring are almost altogether so, because it was my

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* Civil Engineer, Derry, N. H.

intention in this paper simply to allude to congested districts in cities. It is a very great problem to the underwriters to-day, that of the congested districts, where there is a chance at any time that a fire may get beyond control in any one of the buildings and menace all the others in the district. Now, there is scarcely any manufacturing in a congested district, because the rents are too high for that purpose. The manufacturing risks, as a rule, which are equipped with sprinklers, are outlying, either semi-detached, around the outskirts of cities, or altogether detached in the suburbs and country.

I might add that the sprinkler system is a subject in which I have been very much interested, and it has been of late years extending to classes of property quite new to it. As I have said, it was originally developed for mill protection, and they used it in textile mills, for instance, putting it in the picker room only, and then in the card room, and gradually extending to the other less hazardous sections, until to-day it is generally regarded as not paying to leave out any part of the building as free from danger by fire, and that if a plant is to be equipped with sprinklers it is wise to put them in every part of the premises. The extension of the system to new classes includes hotels as one interesting group of property. The Poland Spring House down in Maine, at which you have all stopped, is equipped in all of its laundries, kitchens, servants' quarters, attics, hallways, and throughout the entire upper floor of the hotel with automatic sprinklers. Theater stages are very generally equipped with sprinklers to-day, while the auditorium proper has been excepted. And, as I say, it is going into mercantile buildings very generally; and I even know of one dwelling house which has an equipment throughout the basement kitchen, put in by the owner who knew of the value of sprinkler protection, without any idea of getting insurance reduction for the partial equipment, but simply for his own protection.

Mr. Chase. I think the idea of an electrical alarm is very excellent, and if the manufacturing establishments can be either forced or prevailed upon to adopt it, it will relieve many of the troubles that water-works superintendents have to contend with. I suppose others here have had the same experience as I have had, that it is the manufacturing establishments that hypothecate the most water. They have the greatest use for it, perhaps, and they have a much better chance of getting it without detection, owing to the various ramifications of the supply pipes for fire purposes, than the ordinary mercantile establishments have.

Mr. John A. Gould.* I might make one suggestion in the line of inspection. The concern that I am with has its pipes painted different colors. We have four or five different kinds of pipes, and it is very easy for an inspector to tell whether a pipe is tapped illegitimately or not. We have gas pipes, boiler pipes, steam pipes, fresh-water pipes, and salt-water pipes, and every one is a different color.

Mr. Julius C. Gilbert.† I am a thorough believer in sprinklers for fire protection. When one of the gentlemen here was speaking of what water-works superintendents had to contend with, it brought to my mind a little incident which happened about two years ago. I was called to a large factory which was supplied with sprinklers, because they could n't get any water through the pipe; we went down under the factory, and there we found a six-inch pipe frozen solid for about seventy-five or eighty feet, which had pulled apart about four inches. The windows had been left open in very cold weather. Well, while we were contemplating what was to be done a man came rushing down to us and said, "The insurance inspector is here; what shall we do?" And I said, "We'll fool him." We talked it over a few minutes, and decided upon a little strategy; and we opened some valves which were not connected with the fire service at all, and we showed the inspector that we had a first-class pressure all around the factory, and after taking him all around through the whole establishment we sent him off happy, believing that everything was all right. Well, we felt pretty good over it, but of course we repaired that pipe as soon as possible, and thawed it out and had everything all right and the water on before we went to sleep that night. I want to say one thing in regard to these insurance inspectors. I know that there are lots of men sent out to inspect who don't seem to know anything more about a system of piping than a boy two years old, and if any one wants to play any tricks on them it is very easy to do it. I would suggest that they send out men who know their business, and in such a case as the one I have spoken of I think it is excusable to play a little trick.

Mr. Horace G. Holden.‡ I would like to inquire of Mr. Crosby what he considers the best available hydrant pressure in a residential portion of the city, where the buildings are rarely over two stories in height?

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*Civil Engineer, Boston Gas Light Company.

† Superintendent, Whitman Water Works.

‡ Superintendent, Nashua Water Works.

Mr. Crosby. Of course any figure is purely arbitrary. I would say that seventy-five pounds pressure maintained at the hydrant is the ideal pressure for house service in outlying city districts. It means a pressure at which streams can be attached and handled by hand without difficulty, and it will provide a stream which is sufficient for buildings of that height, and even for buildings of quite a bit greater height.

As regards the insurance inspector, this gives me a chance to get back a little. I won't avail myself very much of the opportunity, however, but will say I am glad to find out it is n't the water-works department alone which is being imposed upon. That is a tale I have heard so often that I had almost come to believe that really we were asking for a great deal more than we ought to, and it was a shame to impose so upon the water-works department. Now, of course I am willing to admit that a great many insurance men whom you meet don't know anything at all about a water-works system, or a sprinkler system, or anything of that kind, although they may ask you questions along those lines and attempt to give you an impression that they know more or less; you can generally see that they know less. But the fire insurance business is a very large one, and divided into a number of specialties to-day. There is the broker who places the insurance for the property owner. He is nothing more than the agent of the property owner, and he is looking after his interests, trying to get him the best rate of insurance, the best companies, and the best form of policy. Now, the broker once in a while may ask you questions, and, in many cases, it will be evident he does not know much about the fire protection of buildings. You must not confuse him with inspectors from the insurance company. Again, there are local agents. Many of them to-day are very fully posted about matters of fire protection, while others don't know anything about it. Then there is the underwriter, who has the general policy of the company to look after, as regards losses and rates and forms of policy, and there is the adjuster of losses, who may not know anything at all about sprinklers, and yet at some time in his career he may come in contact with you.

Now, outside of these classes there is the engineering department, which is maintained in all parts of the country to-day, and which has inspectors in its employ who are supposed to know their business. Ten or fifteen years ago there was very much less known about fire protection engineering than there is to-day. The sprinkler system

has largely developed within that period. The thermo-electric fire alarm has entirely developed within that period, and many other types of fire extinguishing and fire notification apparatus. It is our endeavor to secure inspectors who know their business, and it is safe to say that we have a great many of them who do, and we don't wish to have any who do not. So I think when you come in contact with these men they will as a rule be able to meet you on your own ground, and that they will ask nothing of you that they ought not to, and I am sure that they will appreciate any service you may be able to render them.

Mr. Gilbert. I would n't like to have the gentleman think that we are not all interested in these things, and I can assure him that whenever I have had an inspector come to me I have used him as a gentleman; and if I did n't think he knew all about the matter, I tried to show him about it and do everything I could for him. We know what the insurance people do for us, and we try to help them all we possibly can. But I thought it was all right to tell a good story.

Mr. George F. Chace.* In regard to the question Mr. Holden asked about this matter of hydrant pressure, there is just one point which may be of interest that I recall in my experience. Some years ago, for an experiment, we tested the conditions of the fire service around a certain mill. The buildings were approximately of the size already mentioned, not more than two or three stories, and with fifteen streams through $1\frac{1}{8}$-inch nozzles, which were entirely satisfactory to the inspector, who showed he was in every way a shrewd man and understood his business, the gage at the hydrant showed sixty-five pounds pressure.

Mr. Crosby. Will you allow me just one word more, Mr. President, about a matter which has occurred to me since this discussion first began? In inspecting sprinklered risks in the last six months we have found forty-three gate valves controlling water supplies to sprinklers entirely closed. In a majority of cases this occurred in well-managed plants, where the fact was a humiliation to the superintendent or the proprietor; and yet it had taken place right under their noses, where the valves were in charge of a well-paid engineer and master mechanic, and where the valves were in sight and were passed by responsible people perhaps many, many times during each day. Now if that occurs inside of buildings, in connection with

* Superintendent, Taunton Water Works.

valves in sight, important valves supervised by well-paid and intelligent men, what must be occurring underground, in the city streets, where valves are being shut and opened by subordinates, for the purpose of making extensions or repairs or taps to buildings?

One important matter in this connection came to my notice about a year ago in a very large city in New England, where the yard main service was fed by a twelve-inch connection from the public main in the street. An inspection, which happened to be thorough, revealed the fact that the water which was expected was not forthcoming, and eventually we found that the twelve-inch gate valve in the street main was closed. Further investigation with a very obliging superintendent of water works revealed the fact that an extension of the main down to a few dwelling-houses, made a week before, had caused the closing of that valve, and "Pat Mulcaney," or some one else, was supposed to have gone around there with a wrench and opened it, but he had forgotten so to do. When he was brought to task he said he had opened it, but he evidently had not, for the valve was closed. Now, I am rather curious to know what system of inspection is practical for these water-works valves, which must amount to many hundreds in a city of any size. Upon asking the question in various places I have found that almost always some arrangement for seeing that the valves were open had been made. Very often the man whose duty it is to look at the hydrants spring and fall, and see that they are in proper condition, is also supposed to look at the valves throughout the city streets; but upon further investigation I would find that the man had really not gone to these valves, as it would turn out, unless he had learned that they had been closed for some reason. I would like for my own information to know if there is anywhere a regular system of inspection and examination of valves by thoroughly responsible parties.

President Cook. The question that Mr. Crosby has raised has surely put the water people on the defensive. There is no doubt that the inspection of the street valves should be in charge of a competent person. I hardly think there is a superintendent here who has not at some time during his experience found one or more valves closed which should have been open. I know I have, and I am willing to admit it.

Mr. R. J. Thomas.* I would like to speak of a system of testing and inspecting gates that we have in Lowell. The city is divided

* Superintendent, Lowell Water Works.

into three districts, and we have two men for each district who go around and inspect every gate box and service box, and also examine every gate, — put a wrench on it and see whether it is open or closed, and operate the valve slightly so as to see if the stuffing box is tight. They also do the same with the service cocks, going over the territory as often as they can during the summer season, or probably from the first of April until January, if the weather is favorable. Any valves which are closed are readily found in that way. The men make a report every day of what they have done the day before, and we have a record of their work for every day they are out, what gates they have examined, what service boxes, and everything they have done on the street. In that way, with six men doing that work all summer, I think there is n't much danger of a gate being left closed unintentionally.

PURIFICATION OF SEWAGE BY BACTERIAL METHODS.

BY LEONARD P. KINNICUTT, D.SC., PROFESSOR OF CHEMISTRY, WORCESTER POLYTECHNIC INSTITUTE.

[*Read September 19, 1900.*]

The danger from pollution of a water supply by the refuse of communities, their habitations, streets, and factories, is a constant source of anxiety to the water-works engineer, and it is on this account that I have been asked to address you at this time as to the work that has been done during the past few years on sewage purification and disposal.

The earliest method of sewage disposal was to run the waste products of the community into the nearest river or stream. In a sparsely settled region this caused little complaint; but as the district became inhabited and the towns and villages upon the stream increased in size, it became apparent that this method, though removing the filth from one's own door, would endanger the health and comfort of a large part of the community. It was then that the question of sewage purification and disposal became the subject of scientific inquiry. Without going into any detail as to the early work done upon the subject, I will only state that it resulted in the general adoption of either sewage farming or chemical precipitation as the best means of destroying the obnoxious substances contained in sewage. Sewage farming was based on the idea that plant life was capable, of itself, of decomposing the complex organic matters contained in sewage, and that its capacity to do this work was almost without limit; consequently it was thought that sewage could be applied continuously to cultivated land, and, if vegetation was not drowned out, not only would perfect purification take place, but an immense profit could be derived from making use of the polluting substances for plant food. So firmly were these ideas, especially the manurial value of sewage, implanted in the English mind, that the most marvelous undertakings were planned, and to-day at Barking one sees a tunnel which was started to carry the sewage of London one hundred miles into the interior, with the idea that the tunnel

should be tapped at certain intervals and the sewage sold, at I know not what price per thousand gallons, to fertilize the land. This is hardly less startling than the idea of recovering the gold that is in sea water.

Treating sewage with chemicals was an attempt to remove not only suspended matter, but also the soluble decomposable substances, it being believed that certain chemicals like iron or aluminum sulphate had the property of uniting with the soluble organic substances, forming insoluble compounds, and that by using suitable chemicals all the polluting matter could be removed. It was also conceived that a profit might be made by this process in selling the precipitate formed as a fertilizer, and over two hundred different patents have been taken out for thus treating sewage.

To-day neither of these methods is considered as successfully accomplishing its object. Sewage farming has invariably ended in failure, except in those few cases where the land was of an exceptional character and of very large area compared with the population to be served, as one acre to fifty persons. Chemical precipitation only removes the suspended matter, all the soluble putrefying substances still remaining in the effluent; and this effluent is almost as obnoxious as crude sewage when run into a water course. Until 1890, however, these two methods were the only ones used on a practical scale. In that year the Massachusetts State Board of Health published their Report on the Purification of Sewage and Water, and showed by a series of careful experiments that under proper conditions all the decomposing and polluting substances in sewage could be destroyed by micro-organisms which are contained in the sewage and known under the name of bacteria; and all methods by which organic matter in sewage is destroyed by aid of bacteria, under conditions controlled by man, are now classed under the general term *biological or bacterial purification of sewage.*

Bacteria are a low form of vegetable organism which multiply by a process of transverse division. Though commonly considered as dangerous enemies, they are, in fact, our greatest friends, for it is only a comparatively few species, those that exist on living matter, that cause disease. The great majority obtain their nutritive material from dead animal and vegetable matter, and resolve these substances into simpler compounds, as carbon dioxide, water, ammonia, nitrates, — which are the food supply of higher vegetable life. Were it not for the presence of these bacteria, disposing, as they do, of

effete organic matter and changing it into plant food, human life on this earth would, seemingly, be impossible. These are the bacteria that are present by the hundreds in a cubic foot of air and in a cubic centimeter of so-called pure water, and by the millions in a cubic centimeter of polluted water, or of sewage.

Bacteriology as a science may be said to date from Pasteur's experiments on the causation of the putrefaction of beer and the souring of wine, in the middle of the present century; and it is only at a very recent date that there was any reliable knowledge as to the action of bacteria in the purification of sewage.

Fresh sewage contains, in immense numbers, the class of bacteria which live on dead organic matter and which cause its decomposition. These bacteria can be roughly divided into two great groups, each containing numerous species. These groups are called the anaërobic and the aërobic groups. The anaërobic group embraces all those species that live, grow, and multiply best out of contact with air and light; the aërobic, those species that live, grow, and multiply only in contact with air. Each group plays its own special part in the destruction of the effete matter contained in household waste. The anaërobic bacteria act first. They disintegrate the solid animal and vegetable matters, liquefy them, and bring them into solution. The aërobic bacteria act upon the disintegrated and liquefied compounds and, by a process of oxidation, change them into harmless gases.

For the destruction of dead organic matter both groups of bacteria are necessary; the anaërobic to disintegrate and liquefy the complex organic substances, the aërobic to change those simplified and liquefied compounds into harmless products.

Taking this as a brief outline of what takes place in the decomposition of excreted and effete matter, we are now in position to review the various methods classed under bacterial treatment of sewage.

As I have stated, the credit of showing that sewage can be successfully purified on a large scale by bacterial treatment belongs most certainly to the Massachusetts State Board of Health. Their experiments showed that all that was necessary to completely destroy dead organic matter was to provide conditions favorable to the action of bacteria. These conditions they believed were fulfilled by providing suitable material on which the micro-organisms could be retained, surrounding these micro-organisms at certain intervals with air, and providing periods during which they could rest. A suitable

material was sand, from four to five feet in depth, and the surrounding the bacteria with air at definite intervals, and allowing periods of rest, was accomplished by under-draining the sand and by allowing the sewage to flow on the sand only six hours out of each twenty-four. The combination of these conditions gave us the process known as Intermittent Filtration.

Fig. 1 gives a section and ground plan of four of the sixteen experimental intermittent filtration beds of the sewage plant at Worcester, Mass., and also a diagram showing the valves controlling the flow in the feed pipes and in the drains.

The beds are of coarse sand, from which all pockets of clay and quicksand have been removed. They are each of about one acre superficial area, and are divided from each other by dikes, those containing the feed and drain pipes being raised six feet above the level of the beds, while those running perpendicular to these are only eighteen inches high. In order that certain of these beds should be fairly water-tight, the dikes surrounding them are lined with tamped clay. The drains of Akron pipe, laid with open joints, are six feet below the surface of the bed, and are fifty feet apart, the outer ones being twenty-five feet from the edge of the bed; the first hundred feet of pipe in each bed is 10-inch pipe, the remainder is 8-inch. The drains connect with two 24-inch pipes, placed in the dikes between the beds, and by the aid of valves the drainage of each bed can be separately collected in order that the exact action of the bed can be tested.

The feed pipes are eighteen inches in diameter and are connected with split pipes, which in four of the beds extend across the entire distance of the bed in order to give an even flow over the whole surface of the bed, and the flow upon the bed is regulated by molasses gates placed in the manholes at the four corners of each bed.

By the process of intermittent filtration it has been shown that about 100 000 gallons of domestic sewage can be purified in each twenty-four hours on one acre of sand bed area, so that the danger of subsequent putrefaction is removed; and that using only from 20 000 to 30 000 gallons per day, the product obtained is, as far as chemical or bacterial analysis can show, as pure as spring water.

The work of the Massachusetts State Board of Health, valuable as it was, still left unsettled a number of important points, among which the most salient were: How could the sewage of cities be purified by bacteria where large tracts of sandy soil did not occur?

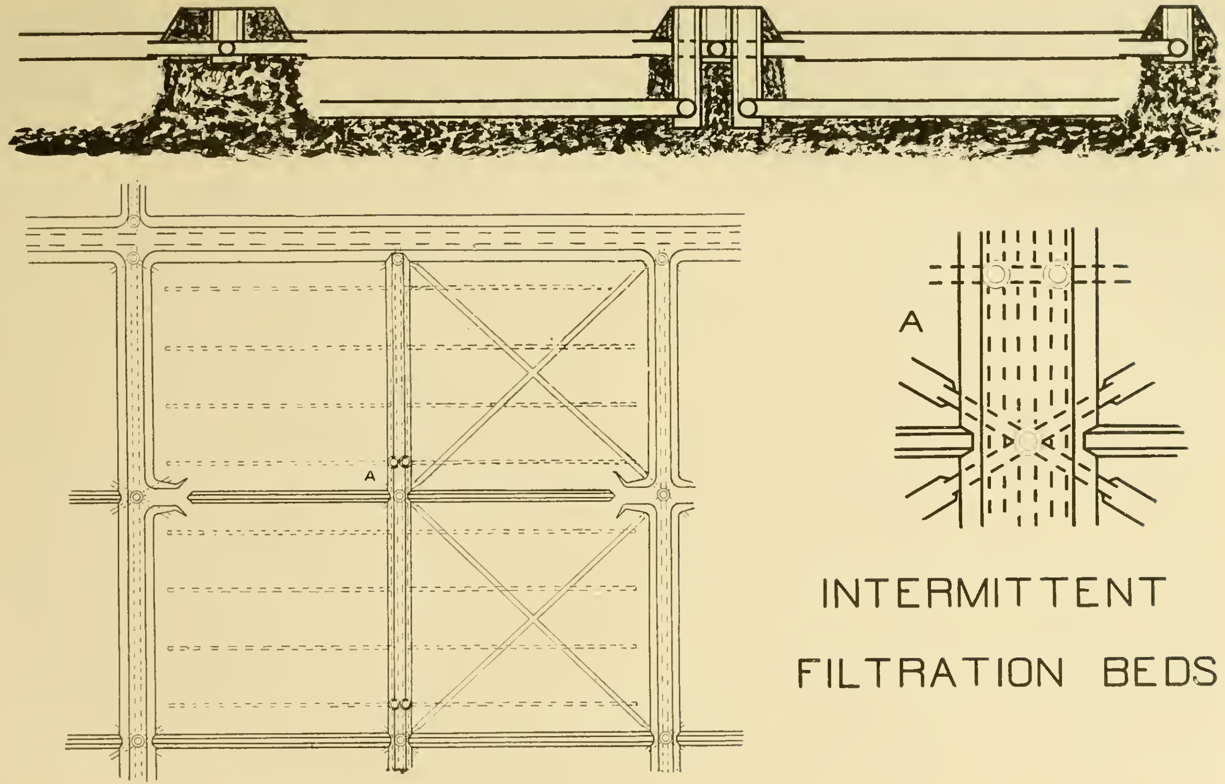

FIG. 1.

How could the large amount of suspended matter, like paper, wool-waste, and the other various forms of cellulose not easily acted upon by bacteria, be prevented from forming a layer and coating over the top of the sand, thus partially clogging up the sand area? Could sewage containing large amounts of manufacturing waste, especially free acid and iron salts, be treated bacterially?

The quantity of sewage that could be treated by intermittent filtration with continuous success had been shown to be not over 100 000 gallons per acre per day, a quantity so small as to be quite useless for towns and cities which would be obliged to construct beds with sand not *in situ*. This point was quickly perceived in England, where sand *in situ* is not of common occurrence, and the bacterial sewage work of England started with the problem, Can the amount of land required by the intermittent filtration method be so reduced that the construction of artificial bacteria beds will be a practical possibility?

The first work in this connection that need be mentioned is that of Dibdin and Thudichum. The experiments of the Massachusetts State Board of Health, broadly speaking, had been along lines followed in the purification of water. Dibdin and Thudichum argued that in sewage, containing, as it does, such vastly greater quantities of organic matter, the bacteria should be allowed a longer time for action than could be obtained by allowing the liquid to pass through a sand bed, and that a greater amount of work could be obtained from the bacteria if the bed were allowed to remain full of the liquid for a certain number of hours. All the micro-organisms thus being kept in contact with the liquid, they would be afforded a better opportunity for changing the organic matter into mineral matter, and the area necessary for the purification might be reduced.

The first experiments were made at Barking, not on crude London sewage, but upon sewage from which the suspended matter had been removed by chemicals. A water-tight bed, covering an acre in area, was constructed. At the bottom perforated drains meeting in a common trunk sewer were laid, and the trunk sewer was provided with a valve so that the sewage could be kept in the bed, or the bed emptied quickly, as desired. The bed was then filled with broken coke to a depth of three feet.

The method of using the bed was as follows: The valve in the trunk drain was closed, the bed was filled to the level of the surface with the above-described effluent, which contained about 0.7 parts albu-

minoid ammonia in 100 000 parts, the bed was allowed to remain full two hours and then emptied, the emptying occupying about two hours. This process was repeated three times a day except on Sundays, the bed thus being allowed to remain empty from twenty-four to thirty-two consecutive hours each week. Working in this way, the bed passed on an average 1 000 000 gallons a day, including all times of rest, and the amount of purification determined from the albuminoid ammonia was from sixty-six to seventy-seven per cent.

Though the amount of purification thus obtained did not compare with the results of intermittent filtration, the result was surprisingly good when the amount treated per acre was considered, and seemed to show that the theory of Dibdin and Thudichum as to longer and more intimate contact of the sewage with the micro-organisms was correct; and Dibdin was encouraged to carry on further experiments at Sutton, England, using crude sewage. A bed similar in arrangement, though of much smaller area, was constructed and filled, not with coke, but with broken burnt clay; and crude sewage, which had received absolutely no treatment except screening, to remove the grosser suspended substances, was run upon the bed. The time required for filling the bed was about one hour; it was allowed to remain full for about two hours and then emptied; the time occupied in emptying it was one and one half hours; the bed was then allowed to rest for two hours, after which it was again filled. The rate of flow on this bed averaged about 770 000 gallons per acre per day, rest periods included. The effluent, as I have seen it, has been clear and without strong odor, and the analyses made three or four times each month, from November, 1896, to March, 1898, showed that the "oxygen consumed" had been reduced from 4.66 parts per 100 000 to 1.77, and the albuminoid ammonia from 0.85 to 0.296 parts in 100 000, the purification equaling about sixty-four per cent. The amount of nitrification had, however, been low, only 0.66 parts of nitrogen in 100 000 parts of the filtrate being found in the form of nitrites or nitrates.

This series of experiments substantiated the results obtained at Barking, and also proved that a far better purification of sewage could be obtained in the above manner, without the formation of sludge, than by any process of chemical treatment, which, at the best, only removes fifty-two per cent. of the total organic impurity.

The effluent obtained, however, from crude sewage by the above plan, and with a bed treating over 700 000 gallons per day per acre,

does undergo secondary putrefaction, gives off odors, and pollutes small water courses.

Mr. Dibdin at once saw this to be the case, and perceived at the same time that a further purification would undoubtedly be accomplished by allowing the partially purified sewage to come in contact with a second bacteria bed; reasoning that if the first bed removed sixty per cent. of the polluting matter, why would not a second remove sixty per cent. of that which still remained? The experiment was tried; the filtrate from the first bed was run upon a second bed of the same size and construction as the first, filled, however, with burnt clay, all of which would pass a half-inch mesh, the method of working the second bed being exactly the same as with the first. The results were satisfactory, for by this double contact a purification equaling eighty-two per cent. had been accomplished, and the effluent from the second bed did not undergo secondary putrefaction or pollute a small water supply.

This was the beginning of what is known as the Double Contact Bacterial Method of purifying sewage, the action of which has been very carefully studied on a large experimental scale during the past year at Manchester, Leeds, Sheffield, Leicester, — in fact, in almost all of the large cities of England; and it is the method that has been reported on so favorably by the expert commission appointed to recommend a method of sewage purification for the city of Manchester — whose dry weather flow of sewage is twenty-five million gallons per day — that the city council of that city have adopted this method, and have accepted plans and specifications for the construction of a plant at the estimated cost of $2 400 000.

The following diagram (Fig. 2), taken by permission from a plate in the commissioners' report above referred to, gives a section of two beds of a double contact system and a ground plan of a contact bed empty, showing the under-drains, and a contact bed full of the filling material, showing the carriers for applying the sewage.

As is seen, in the double contact system the beds must be on two levels, so that the under-drains from the first bed are at least on a level with the top surface of the second bed, and so arranged that the effluent from the first bed can be run directly upon the second bed, or into the effluent channel. The valves in the under-drains are so arranged that the beds can be left filled with the purified sewage or completely emptied.

In making contact beds the ground is excavated to the depth of

TWO BEDS OF THE DOUBLE CONTACT SYSTEM

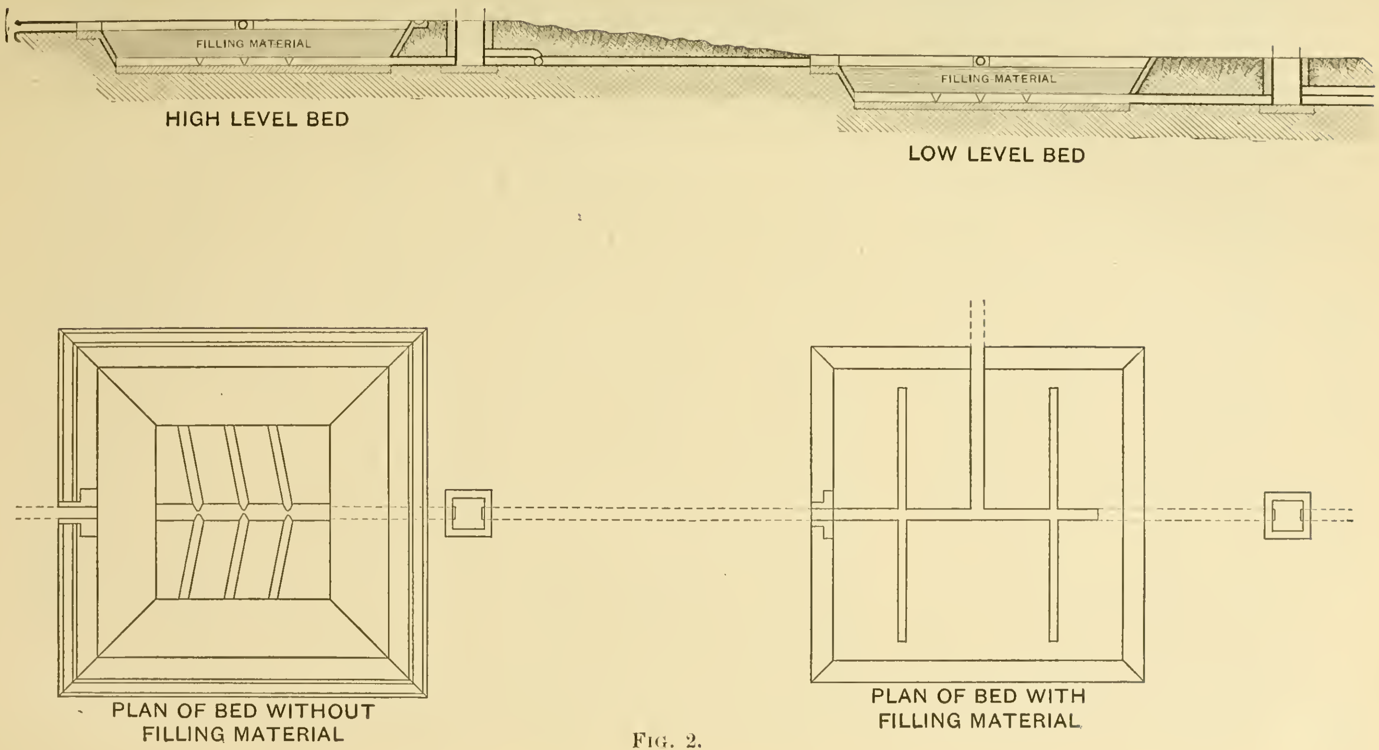

Fig. 2.

about four feet, and the sides and bottom made water-tight; best by cement concrete six inches thick rendered with mortar one and one half inches thick. The bottoms of the beds are channeled to receive drain pipes, or the channels themselves serve as drains, being covered with perforated slabs. The effluent from these drains passes into a main drain, which is so constructed that by the use of manholes and valves the effluent can be carried from a high level to a low level bed, or can be delivered directly into the effluent channel. The construction is also such that the effluent channels can be kept full of the purified sewage or completely emptied. The sewage carriers are so arranged that the crude sewage can be delivered upon any of the beds, either high or low level, and is distributed on the beds, as a rule, by wooden carriers with perforated bottoms.

The beds are filled to a depth of three feet with almost any kind of hard, porous, jagged material. Dr. Hill, of Birmingham, prefers coal; Mr. Scudder, of Manchester, clinkers or cinders. At the Manchester experimental works coke is used; at Sutton, burnt clay. The question of the best substance to use for the filling material is a disputed one. In my opinion the material should be sufficiently hard so as not to be easily broken down; it should be more or less porous, so as to have a large water-absorbing area; and it should have a jagged surface, on which the gelatinized micro-organisms can easily be retained; and possibly broken iron slag would be a better material than any of those mentioned. Whatever the material may be, it is carefully sifted, and only that portion which passes a $1\frac{1}{2}$-inch mesh and is rejected by a $\frac{1}{4}$-inch mesh is used in filling the bed.

In using the contact bed system of treatment, the upper level bed is filled as quickly as possible with sewage, usually in a half-hour; the sewage is, as a rule, allowed to remain two hours in the bed, and then, if the determination of the amount of oxygen consumed or other test shows it to be desirable, it can be run upon a low level bed, or if sufficiently purified, directly into the effluent channel. The emptying also occupies one half-hour. If the effluent from the high level bed is run upon the low level bed it is allowed to remain on the low level bed from one to two hours, as the case requires, and then passed into the effluent channel. In a triple contact system it can be run upon a third bed on a lower level than the second. After a bed has been used it is allowed to remain empty from three to four

hours before again being filled. Used in this way the same bed can be filled three or four times a day.

The method of double or triple contacts has, it seems to me, placed in our hands a very delicate piece of apparatus, which might be called a bacterial machine, and which can be adapted to the work required in much the same way as any piece of machinery in the mechanical arts. For instance, with a very weak sewage, one contact can be used, and that not of two hours, but of one hour only. In another case, with a stronger sewage, two contacts, each of two hours, or one of two hours and the other of one hour, can be tried; while with certain kinds of sewage, which might come down the sewers at certain intervals during the day, it would be possible, in a suitably arranged plant, to use three contacts.

As to the amount of sewage that can be purified by the double contact system, it has been shown by actual work that 700 000 gallons of crude strong sewage can be purified per acre per day, so that the effluent will not undergo secondary putrefaction, either unmixed or mixed with river water.

A comparison of the results obtained by intermittent filtration system, illustrated by the results obtained at Marlboro for the year 1898, where the amount of sewage treated was 90 000 gallons per acre per day, with the results obtained at Manchester using the double contact method, and treating 700 000 gallons per acre per day, is shown in the table below. There is no question that the intermittent filtration system gives a much purer product than is obtained by the double contact method. What can be claimed for the double contact method is that with an area of filtration only one ninth of that required for intermittent filtration it gives a product that is sufficiently purified to prevent its causing any trouble or nuisance, even when emptied into a very small water course.

ANALYSIS OF SEWAGE EFFLUENT.

Parts in 100 000.

	Free Ammonia.	Albuminoid Ammonia.	Oxygen Consumed.	Nitrogen as Nitrites, Nitrates.	Chlorine.
MANCHESTER, ENGLAND.					
Septic tank	3.20	0.390	7.00	. . .	16.4
1st contact bed	1.80	0.170	2.20	0.052	16.0
2d contact bed	0.51	0.075	0.69	0.870	15.7

ANALYSIS OF SEWAGE EFFLUENT — *Continued.*

Parts in 100 000.

	Free Ammonia.	Albuminoid Ammonia.	Oxygen Consumed.	Nitrogen as Nitrites, Nitrates.	Chlorine.
MARLBORO, MASSACHUSETTS.					
Sewage	1.90	0.4600	2.59	0.15	4.91
Effluent	0.62	0.0328	0.34	0.56	5.00
PER CENT. REMOVED.					
Manchester	84.1	75.2	90.1	. . .	. . .
Marlboro	64.6	92.0	86.9	. . .	. . .

These results are very satisfactory and show that for a city so situated that large tracts of sand cannot be obtained, the bacterial treatment of sewage is still a possibility. The method, however, is open to the same objection as the method of intermittent filtration; namely, the clogging up of the beds by suspended matter and substances not easily acted upon by bacteria. This danger, it seems to me, is much greater in the beds of the double contact system than in the beds of an intermittent filtration plant, as the area and cubical contents of the former are so much smaller in proportion to the amount of sewage treated. This objection to the double contact system is now fully recognized, and, from the experiments made at Leeds during the past year, it would seem that double contact beds cannot continuously, for any great length of time, purify crude sewage; or, in other words, if crude sewage is applied directly to double contact beds, the filling material in the beds must be entirely removed every few years.

In our brief outline as to the action of bacteria in decomposing animal and vegetable matter, we noticed that the decomposition was brought about in two stages; the first stage consisted in the decomposing of the grosser and more complex substances occurring in sewage and bringing them into solution by means of the anaërobic bacteria, which live out of contact with air; while the second stage consisted in the complete decomposition and nitrification of the simplified products by the aërobic bacteria, to which air is a necessity. In all bacterial treatment of sewage these two stages must take place, and in the system of intermittent filtration beds and contact beds the two stages of purification are being carried on more or less at the same time. If in either of these systems too little air is supplied, or too much sewage applied to the beds, which amounts to

the same thing, the aërobic or nitrifying bacteria cease to work, their place being taken by the anaërobic bacteria which are unable of themselves to finish the process; and whenever the anaërobic bacteria have obtained the upper hand, as is the case when a bed is overworked, the bed becomes clogged and the product foul. Can this be prevented? Is it possible to treat sewage in two different stages? As I have mentioned, one of the salient questions left unsolved by the Massachusetts State Board of Health was, Could the clogging up of the surface of a sand bed area by suspended matter be prevented? This question, as well as the question which we have just considered, of increasing the amount of sewage that could be applied to a given area, has received careful study in England, and as a result we have what is now known as the Septic Tank Treatment, by which treatment the first stage of sewage purification is brought about before the sewage is allowed to come in contact with the filtration areas.

By septic treatment is meant confining the sewage for a given time out of contact with air and light. In itself it is the method of our forefathers, the cesspool, and the reactions that take place in the septic tank are similar to those which take place in cesspools, resulting in bringing into solution a large amount of suspended animal and vegetable matter. The use of a tank for this purpose is not new. Dr. S. Rideal (Cantor lecture, January, 1899) mentions the use, as early as 1858, of a large underground tank by a boarding school in England for the treatment of the sewage of three hundred persons, and Mr. Rudolph Hering has lately pointed out that the Mouras Automatic Scavenger, described in the *Cosmos les Mondes*, December, 1881, and January, 1882, was a true septic tank.

Mr. Scott-Moncrieff, the well-known sanitary engineer of Ashstead, England, was, I believe, the first to recognize that the bacterial purification of sewage took place in two stages, and that the first stage should serve as a prelude to further treatment. In 1891 he built at Ashstead a small plant in which the purification of the sewage should take place in two stages. It consisted of a closed tank filled with stones, for the partial liquefaction of the solid matter in the sewage, and of open trays containing coke, for the second stage, or where nitrification was to take place.

Fig. 3 shows the liquefying tank and the coke trays used by Scott-Moncrieff. The sewage first enters the grease trap *A* and then passes into the space *B* of five cubic feet capacity, which is under-

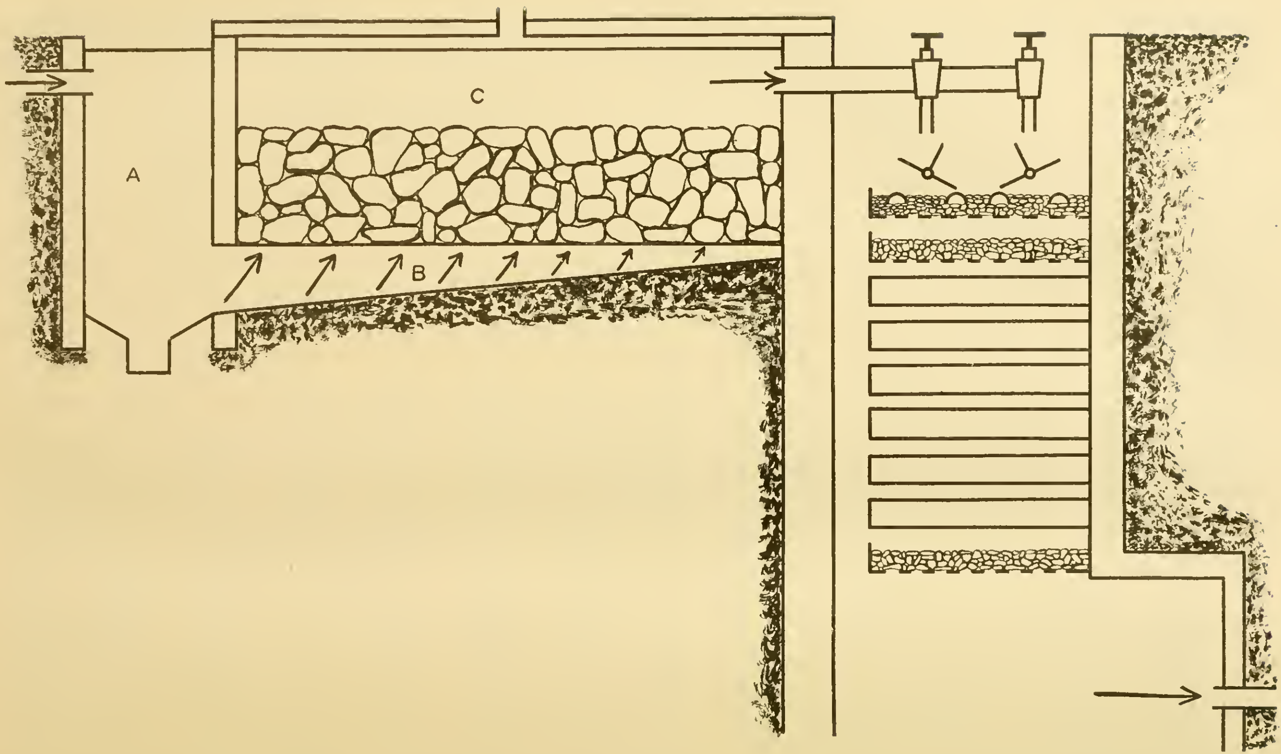

FIG. 3.

neath the gratings of the liquefying tank *C*. It then passes upwards through a bed of small stones inside the tank, and then by means of distributors passes to the uppermost of a series of nine perforated trays, containing coke, supported vertically over one another, about three inches apart. Each tray has an effective area of about one square foot, and contains seven inches of coke, broken to about one inch diameter. The time required for the liquid to pass through the nine trays is about ten minutes.

In the tank the anaërobic action takes place, and on the coke in the trays the aërobic. The anaërobic or septic action that took place in the liquefying tank when used at Ashstead was so effective that it is reported that the solid deposit of seven years from a household of ten persons was absorbed on nine square yards of land, causing no distinction in appearance between this soil and the surrounding; and the second stage of purification, nitrification, was so perfect that all the decomposable matter was destroyed.

The credit, however, of showing that a modified cesspool could be advantageously used for the preliminary treatment of the sewage of cities and towns belongs to Mr. Cameron, of Exeter, England. The process was named by him the Septic Treatment, and it is by this name that it is now known.

He built at Exeter an underground tank of cement concrete, 65 feet long, 19 feet wide, and of an average depth of 7 feet, and having a capacity of 53 000 gallons. The tank was covered with a

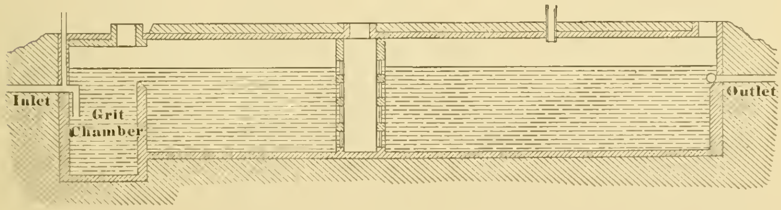

FIG. 4. — SECTION OF SEPTIC TANK.

concrete arch, and, as is shown in Fig. 4, a portion of the tank near the inlets was made about three feet deeper than the rest and partially cut off by a low wall, forming a couple of pockets or grit chambers, to retain sand, grit, and road washings. The inlet was carried down to a depth of five feet below the surface, so that air could not make its way down with the sewage, and also so that gases

could not escape from the tank back into the sewer. The effluent outlet was also below the level of the liquid, and, to avoid any current that would be liable to carry with it any floating matter from the surface, a cast-iron pipe was carried across the whole width of the tank fifteen inches below the surface, and on the lower side of this pipe there was a continuous opening of about one-half inch in width. An iron pipe, about one and one-half inches in diameter, extended out of the top of the tank to allow the escape of gases which were formed, and the sewage in the tank could be inspected by descending into a manhole constructed in the center and having glass windows.

At the plant at Exeter there are also five single contact beds 36 feet long, 20 feet wide, and 4 feet deep, made water-tight and filled with crushed clinker or coke breeze. (See Fig. 5.) Such beds are admirably adapted for the cultivation of aërobic bacteria, and the liquid as it comes from the tank, having undergone the first stage in the process of putrefaction, is now in just the right condition to be acted upon by the aërobic bacteria.

In August, 1896, the main sewer of St. Leonard's, a suburb of Exeter, with a population of 1 500, and an average daily flow of sewage of 57 000 gallons, was connected with the tank, and the above volume of sewage has been continuously passed through the tank since that time. The effluent from the tank falls over a wall about one foot high, which effects slight aëration, and then by means of the alternating gearing, devised and patented by Mr. Cameron, is caused to pass automatically to one or the other of the beds.

Visiting the plant, the effluent from the tank first strikes the attention. It is a brownish-colored fluid, free from palpable suspended matter, but does contain solid matter in a state of very fine subdivision. It has a decided odor, but at the four different places where I examined it the odor is not more offensive than that given off from the first or second basin used in the chemical precipitation process.

The liquid in the tank is covered with a thick, floating mass, dark brownish yellow in color, through which bubbles of gas are continually breaking. This floating mass was formed during the first six or eight weeks the tank was in operation, and is said not to have increased much in thickness since that time. It appears to be composed of organic matter, but in fact I believe it is principally a mass of micro-organisms, and it is not till this floating mass has been

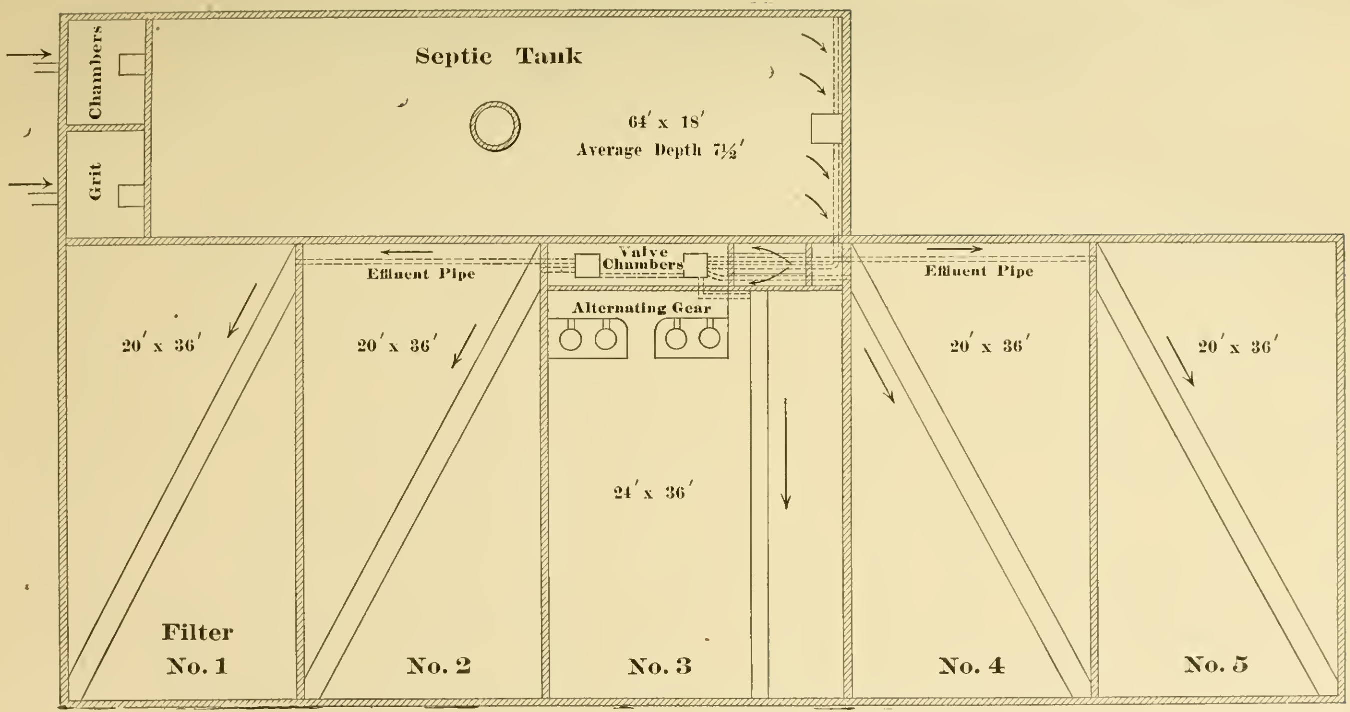

FIG. 5.—PLAN OF SEPTIC TANK AND CONTACT BEDS.

formed that active septic action takes place. At the bottom of the tank there was, last summer, a deposit two to three feet in thickness, the accumulation of three years, as the tank has never been cleaned out. This deposit looks like sewage sludge, though it contains much less organic matter. From the iron pipe at the top of the tank issues a volume of gas which, when ignited, burns with a colorless flame about one foot in height. The unignited gas has a marked odor, but does not contain appreciable amounts of sulphide of hydrogen.

What are the changes that take place in this tank? The most marked is the disappearance of solid matter, and it has been demonstrated that from one half to two thirds of the total suspended matter is decomposed and liquefied.

The decomposition and disappearance of this large amount of solid matter is explained by the theory that it is caused by the action of anaërobic bacteria. This class of bacteria has, without question, the property of decomposing cellulose and allied substances, with the formation of water, marsh gas, hydrogen, and carbon dioxide, and also the power of decomposing complex nitrogenous substances like albumen into simpler compounds, soluble in water, as marsh gas, ammonia, and carbon dioxide.

In the septic tank there would be both aërobic and anaërobic bacteria, sewage continually entering the tank, but the sewage being practically shut off from air it would be a most suitable environment for anaërobic bacteria, and we would expect that the two changes noted above would be the principal ones that took place.

The cellulose in various forms, as paper, starchy substances, woody fiber, would be disintegrated and finally liquefied ; the complex nitrogenous substances, like albumen, would be broken up into simpler compounds, and those which were originally insoluble in water thus being brought more or less into solution. In these decompositions a large amount of solid matter would also be changed into gaseous compounds, as ammonia, carbon dioxide, marsh gas, hydrogen, and nitrogen. Of these, ammonia and part of the carbon dioxide would remain in solution, while the others, being insoluble in water, would escape from the tank, forming a combustible gas like that escaping from the tank at Exeter.

As a result of these changes we would expect the effluent from the tank to contain more free ammonia than the crude sewage, but much less albuminoid ammonia, and the amount of oxygen consumed

by the effluent to be also much less than that consumed by the crude sewage.

The following analyses of crude sewage and tank effluent show the results actually obtained : —

	No. 1.*		No. 2.†	
	Crude Sewage.	Tank Effluent.	Crude Sewage.	Tank Effluent.
Free ammonia	4.50	7.50	3.60	4.90
Albuminoid ammonia	1.20	0.66	1.40	0.64
Oxygen consumed	4.50	3.10	6.56	4.32
Chlorine	8.00	8.10		

These results are very similar to those which I have obtained in my experimental work at Worcester.

It is not a long step between a closed and an open septic tank, and I doubt if it is known who first saw that similar action must take place in a large open tank as in a closed tank. The conditions, of course, in both cases must be practically the same; no free oxygen can be present in an open tank when full of sewage, and as the sewage contains a large amount of suspended matter, very little light can penetrate down from the surface. I know not who first used an open tank for septic action ; I found them last summer being used experimentally at Accrington, Huddersfield, Leeds, and Manchester, England. In each of these places an old tank which had formerly been used for chemical precipitation had been turned into a septic tank, all the change necessary being to place the outlet so that the effluent opening should be three to four inches below the surface of the liquid, although, of course, in the building of such a tank it would be much better to have the inlet also beneath the surface. In all these places the general appearance of the liquid in the tank was the same, very dark and opaque, the surface coated over with a thick layer of solid matter, and the activity of the action in the tank shown by the thousands of bubbles of gas escaping through this layer of solid matter. The effluent was of a dark brown color, containing suspended matter in a very fine state of subdivision ; but neither the odor given off from the tank nor that from the effluent was so offensive as to prevent its use. That the action which takes place in the open septic tank is very similar to

* Average of a series of analyses made at Exeter by T. B. Perkins, Esq., public analyst.

† Average of a series of analyses made at Exeter by Dr. G. S. Rideal.

that which takes place in the closed tank is shown by a series of analyses I have lately made on the gases given off from the closed and open septic tanks at the Worcester, Massachusetts, Sewage Plant; the gas in both cases containing about the same amounts of marsh gas, nitrogen, and carbon dioxide. This same fact has also been shown to be true by the series of experiments made on the effluent from the two kinds of tanks by Mr. Fowler, of Manchester. He made daily analyses for one month of the effluent from an open tank, and of the effluent from a closed tank, both being supplied with the same sewage. The following table gives the average of these daily analyses. The results, as can be seen, are almost identical: —

AVERAGE OF ANALYSES OF EFFLUENTS.

Parts in 100 000.

	Open Tank.	Closed Tank.
Free ammonia	3.20	3.10
Albuminoid ammonia	0.50	0.51
Oxygen consumed	8.46	8.43
Chlorine	16.40	16.10

I have spoken as though the changes in the tank were solely due to direct action of bacteria. This, however, is questionable. The reactions may be, to a certain extent and possibly even to a very large extent, of a chemical nature and brought about by a class of substances known as enzymes. Enzymes are unorganized ferments, chemical substances which are the products of vegetable and animal life, and which, in minimum amounts, without being themselves used up, are able to break up and decompose large amounts of complicated and insoluble compounds. Thus the enzyme known as diastase decomposes starch; lifase, many fats; cytase decomposes and dissolves cellulose. These enzymes seem to decompose the complex organic substances by what, chemically speaking, is called hydrolysis, — the breaking up of a compound by the addition of water. In this way substances like albumen may be broken up, with the formation of nitrogen, ammonia, hydrogen, marsh gas, and carbon dioxide; substances like cellulose into hydrogen, marsh gas, and carbon dioxide. Many of the enzymes being the products of anaërobic bacteria, they would naturally occur in the septic tank, and a large amount of the decomposition may thus be chemical rather than bacterial.

Whatever may be the exact cause of the changes that take place

in the septic tank, either open or closed, by which suspended matter is brought into solution, the process, at all times when I have seen it, is about as follows: As the sewage enters the tank, the solids gradually fall to the bottom, covered with millions of bacteria. These, or their products, the enzymes, attack the solid matter at the bottom of the tank and gradually decompose it, bubbles of gas forming which collect about the fragments, causing them to rise to the surface; where, a large portion of the gas becoming detached, the solid matter again sinks, and this rising and sinking continues until the solid mass is completely decomposed. At the same time a scum begins to form on top of the liquid, and it is not till this scum is from one to two inches thick that active septic decomposition takes place. Formerly this required at least from one to two months in a new tank, but it has been shown during the past year that active septic action can be started up in a new tank in two or three days, if some of this layer from the top of an old tank is added to the liquid. This reminds one of the action of mother of vinegar, and it is not only most interesting, but of practical importance, as it will add greatly to the efficiency of septic plant installation.

The real practical value of the septic tank is that it destroys suspended matter without forming any very great amount of sludge or precipitate, thus having an advantage over any chemical precipitation process; that it seems to bring cellulose into at least partial solution, thus preventing the coating over of bacteria beds, either those of intermittent filtration or contact, with a layer more or less impervious to water; that it breaks up the more complex organic compounds, forming substances that are more easily acted upon by the nitrifying bacteria than the compounds in raw sewage. In a few words, it is a process which prepares the sewage for subsequent treatment on bacterial beds, either those of the double contact system or those of the intermittent filtration system. And if I were asked what was the most important step in advance that had been made in sewage treatment during the past ten years, or since the report of the Massachusetts State Board of Health, I think I would answer, the recognition that sewage purification should, for the best results, take place in two stages, and the devising of a method, as the septic tank treatment, for breaking up the complex organic compounds and bringing a large part of the suspended matter into solution.

Without some such preliminary treatment, I feel convinced that

any system for treating large quantities of sewage on limited areas, like the double contact system, — which is absolutely necessary for many cities, — is doomed to failure, and I also feel convinced that with the intermittent filtration method much more satisfactory results could be obtained if the sewage first received septic treatment.

Even with the most careful septic treatment of sewage, the length of time a contact bed can be used without renewal of the filling material is still an undecided question. Besides the slow breaking down of the filling material, experiments made during the past year at Leeds show that there is more or less filling up of a bed with certain organic substances, similar in nature to the humus of the soil, which are not removed from the sewage by septic treatment, and which are very slowly acted upon by micro-organisms. The exact nature and effect of this deposition requires the most careful investigation.

It may be said that in the chemical treatment of sewage we have also a method for the removal of suspended matter and preparing the sewage for filtration areas, and this is true; and in cases where sewage contains large amounts of acid and manufacturing refuse, notwithstanding the cost of the chemicals, and the formation of a large amount of sludge, a product most difficult to successfully handle, chemical precipitation might be used to advantage in place of septic treatment.

There is, however, one word of caution regarding septic treatment that I wish to give, and to emphasize at this time. Septic treatment does not consist in running sewage quickly through an open or closed tank; and if the rate of flow is so great that the sewage runs through the tank in much less than twelve hours, there is settling out of suspended matter, but there is very little septic action, and a rate of flow of twenty-four hours is much to be preferred to twelve.

At the beginning of this paper I mentioned that there was also a third important question which had been left almost untouched by the Massachusetts State Board of Health, namely, Could sewage containing large amounts of manufacturing waste be treated directly by bacterial methods? This question has not as yet been answered. Many experiments are now being made, both in this country — for instance, at Worcester — and in England, the results of which may in the near future give us some definite information regarding this point.

I have tried, in the time at my disposal, to give the present status of sewage purification. I have not, however, touched upon a phase of the question that may become a very important feature of sewage treatment, namely, continuous filtration.

As you all know, in the purification of a water supply, the filtration of the water through the sand beds is continuous, not intermittent, as it is in the processes of sewage filtration I have described.

Experiments of purifying sewage by continuous filtration have been made in this country by Professor Drown and the late Colonel Waring, and in England by Scott-Moncrieff, Ducat, Lowcock, Whittaker, and others.

This method has, during the past year, gained in importance by the fact that the new plant for the treatment of the sewage of Salford, capacity 12 000 000 gallons per day, just constructed under the direction of Mr. Joseph Corbett, the borough engineer, and the plant constructed in 1899 by Mr. Wallis Stoddard at Horfield, near Bristol, both use this method of filtration.

At neither of these plants is crude sewage used on the filters, but sewage from which the suspended matters have been removed, either by septic or chemical treatment. At Horfield the partially purified sewage is caused by a specially constructed distributor to rain down on the filter, which is composed of cinders from two to three inches in diameter, so that the liquid is never allowed to do more than moisten the surface. Continuous aëration is thus said to be obtained, and the bed works without any period of rest. Mr. Stoddard claims to be thus able to satisfactorily purify 8 000 000 gallons per acre of septic or chemically treated sewage per day.

It is not yet possible to state what will be the final outcome of this method of filtration. If it is possible, unquestionably, much larger quantities of sewage per acre can be dealt with than by the methods of intermittent filtration.

In conclusion I would say, while I think it is very doubtful if by any practical process of purification a sewage effluent will ever be obtained which is considered as safe to enter a water supply used unfiltered for household purposes, yet it would be a very rash statement to make, in view of the progress that has been made in the last twenty years in the methods of treating sewage, that a degree of purification may not some day be reached that would make such a use of treated sewage justifiable.

DISCUSSION.

The President called upon Mr. Rudolph Hering, of New York, to open the discussion on Professor Kinnicutt's paper.

Mr. Rudolph Hering. Mr. Chairman, ladies and gentlemen: Having this summer examined the principal works of Europe, some of which the speaker has just described, I was particularly interested in his remarks; and I can state that it was the fairest and most truthful statement regarding this subject that I have yet heard on this side of the Atlantic. We were given the impression in America, from various articles appearing in English papers, that a great revolution had taken place in the matter of sewage purification; and that hereafter it might be a very easy and economical matter to dispose of this offensive material which every city has to deal with. We have, therefore, with much interest, watched the progress made in England.

At a number of points in Europe, not only in England, but also in Germany, experiments have been made with these so-called new processes; and as they have now been carried on for one and two years, it was a fairly good time to visit the points last summer.

After having seen nearly all of them, however, I must say that I returned with a good deal of disappointment, because the glowing promises which had been made did not seem to me to have been realized. I found the cities more or less altering their trial works, and excusing this and excusing that condition, with the desire of some to experiment further.

Some cities have reached conclusions fairly satisfactory. For instance, there is a report out quite recently from the city of Leeds, also one from the city of Leicester, and, as Professor Kinnicutt has already stated, quite recently a conclusion has been reached as to what they intend doing also in Manchester. That does not mean, however, that they have solved this whole question; they are simply going ahead and doing something which is better than what they have done heretofore.

In some other cities they are still carrying on experiments, not feeling at all satisfied with the results up to date. Perhaps one of the most thoroughly equipped experiment stations, in this particular line of investigation, is in Hamburg, Germany. There they have been experimenting for two years, and they don't expect to reach satisfactory results for at least a year yet; and also in Charlotten-

burg, a suburb of Berlin, they are making experiments on similar lines.

So I do not think it can be said that in Europe they have reached a final conclusion in regard to this matter. There is no question, however, that we are face to face with a method of sewage disposal, which, in the future, will be of advantage in many cities. You know, and you have heard it said this afternoon, that intermittent filtration, a system which was so highly recommended by the Massachusetts State Board of Health, gives us the purest effluent. Indeed, it is the only means known to-day by which you can get a real purification of sewage, so that the offensive organic matter and probably also the disease germs are thoroughly removed. There are cases where the effluent sewage is, chemically and biologically speaking, equal to the best drinking water; in fact, better than a good deal of the raw drinking water that we furnish our citizens in this country. No other method of sewage treatment comes up to it.

But there are a large number of cases where it is not necessary to purify sewage to that extent, and where we can adopt something which is less expensive at the sacrifice of not turning out such good water. Personally I am of the opinion, and I have held this opinion for many years, that the time is not far distant — in some places it has already arrived — when all of our drinking water must be filtered. In other words, we should not be furnished with any water other than either such that has been naturally filtered, as spring water, or such that has been artificially filtered. In Europe this principle is already being closely followed. There are but a very few cities where the water furnished does not belong to one of these two classes. Vienna gets its water supply from the mountain streams of the Alps; it does not filter it, but it protects it very carefully. Paris gets a part of its drinking water supply — it has, as you know, a double supply, one for drinking and household purposes, and the other for street washing purposes — from mountainous regions, and it is not filtered. Glasgow gets its supply, which is also not filtered, from Loch Katrine. But pretty much all of the other large cities of Europe now have either ground water or filtered water. Liverpool gets its supply from the Welsh mountains, a territory which in our country would generally be considered quite suitable for a water supply without filtration; yet filters are arranged there for the purpose of reducing its color and of guarding it against

any incidental pollution to which a water supply is liable in any country. You can't prevent sick people from going up into the mountains; you can't prevent flies and other insects from carrying disease germs from inhabited places or manured fields to the watershed. So the only safeguard which they recognize in Europe now, and which we surely will recognize later on here wherever we do not yet recognize it to-day, is that all water supplies should be filtered.

Now, if that is the case, sewage filtration is not such a serious matter, particularly in our country where we have so many large rivers and can dispose of the sewage very often by dilution without causing any offense to riparian inhabitants. This subject is of more importance in Europe, where, because they only have about one half the rainfall, their rivers are much smaller than ours. They are, therefore, developing it, and we may get from them, perhaps in a short time, some very excellent scientific results.

I would like to state, with reference to what Professor Kinnicutt said as to the Massachusetts State Board of Health originating the system of intermittent filtration, that it laid the first broad scientific foundation for that method of purifying sewage. It did not originate there, because the chemist of the city of Berlin, Dr. Alexander Müller, as early, I think, as 1865, reported on the fact that the bacteria in sewage were the cause of the purification of the sewage, when it trickled through soil slowly and intermittently. Shortly after that, Dr. Frankland of England made similar statements; and in 1870 an engineer, Bailey Denton, constructed a large filter plant at Merthyr Tydfil, in the English lake region, for sewage purification on the intermittent filtration plan, and this was the first large successful work of the kind. I saw those works myself in 1880. The Massachusetts State Board of Health began its work, I think, in 1887. After it had made its reports we knew exactly what we could expect from soils of a certain character, in the way of sewage purification. Before that time the necessary details were largely a matter of guesswork.

In examining the recent sewage purification plants in England there was one thing which struck me as particularly unfavorable. As Professor Kinnicutt has said, they have to depend on other materials than sand, because there is very little sand in England. They therefore use a good deal of coke and a material made out of clay in the following manner. They pile up layers of clay alternating with layers of coke or coal, and then burn it, so that it makes

a mass of burnt clay, which they subsequently break up in little chunks. It looks like very coarse gravel, and they use that very extensively instead of gravel. However, it is not a permanent material; I have seen it in conditions where it had become fine and crumbly. It had outlasted its original usefulness. It didn't act after some five or ten years as it acted originally. I saw the same deterioration with coke. Unless you get very hard coke, and you can't always get it, it will after a few years crumble and become fine. So that these materials are not permanent, and it is a question for calculation as to whether it is cheaper to get a more expensive permanent material, such as gravel or quartz sand, which will last longer (though it may not purify quite so much sewage at first as fresh coke will), or to occasionally replace the deteriorated coke or burnt clay with new material of the same kind. That is a question which must be decided in each case.

It seems to me that the experiments have not gone far enough yet to show just exactly what are the relative advantages of these different materials, particularly of quartz sand in relation to coke. The reason why they have not gone far with such experiments in England, although they have made a few, is because they do not have much sand to use.

Dr. Kinnicutt. I wish, first of all, Mr. President, to thank my friend Mr. Hering for his very kind remarks on my paper. He is most certainly correct in stating that the idea of purifying sewage by intermittent filtration had been considered long before the Massachusetts State Board of Health began their experiments at Lawrence. In the Royal Commissioners' Report on pollution of rivers and streams, 1870, after reviewing the various methods that had been proposed for the treatment of sewage, they say: "The process of filtration through sand, gravel, chalk, or certain kinds of soil, if properly carried out, is the most effective means for the purification of sewage."

In my remarks regarding the work of the Massachusetts State Board of Health, I only endeavored to convey the idea that the credit for demonstrating that the method was practicable on a large scale and, at the same time, a most effective method, should be given to this board.

I am glad Mr. Hering has referred to the deterioration and breaking down of the various filling materials used in contact beds, for this is one of the points which still require most careful considera-

tion. As he has said, experiments on this subject are now being made in England and also in Germany, and in two or three years we may hope to possess definite information on this subject. Personally, I believe the material should have a jagged, rather than a rounded, surface, as giving a better surface for the retention of bacteria; I think, for instance, that broken quartzite would be a better material than rounded pebbles.

I agree with Mr. Hering when he says that the first reports received from England were too sanguine, but I do think that the experiments that have been made there show that a satisfactory purification can be obtained on a much smaller area than that required by intermittent filtration: by satisfactory purification, meaning, obtaining an effluent which will not, of itself, or when run into a very small water course, undergo secondary decomposition: that, using septic tanks and contact beds, sewage can be successfully treated at the rate of about 500 000 gallons per acre per day. The question that has not, however, yet been answered is, How many years can such beds be used without the renewal of the filling material?

There is no question that a purer effluent is obtained by the intermittent filtration method than by the septic methods, yet the effluent obtained at the various plants in Massachusetts, as at Gardner, Marlboro, and Clinton, is very far from being, in any sense, a drinking water. The effluent has a decided odor and taste, and contains a very large number of micro-organisms; further, in the spring, when, on account of snow and ice, the surface of the beds has remained untouched for a number of months, the top of the beds is covered with a nearly impervious layer of from one quarter to three quarters of an inch in thickness, composed chiefly of undecomposed organic matter. The rate of filtration at such a time is not over thirty to fifty thousand gallons per acre per day.

Mr. T. H. McKenzie.* May I ask Professor Kinnicutt whether there are places in England where in actual practice they are passing sewage through the contact filters and septic tanks, without subsequent filtration, where the effluent is turned into any drinking water streams, and where it meets the requirements of law?

Professor Kinnicutt. In answer to the question asked by Mr. McKenzie, I would say that the methods I have mentioned are as yet too new to have been tried, except on a large experimental scale,

* Civil Engineer, Southington, Conn.

at many places, and that I cannot recall at the present moment any place using the above methods, for the treatment of the total flow of sewage, where the effluent from the contact beds is run directly into a stream used for a water supply; and there is no question, if such an effluent were to be run into small streams, the water should be sand filtered before being used. As to whether the effluent from septic tanks combined with contact beds meets the requirements of the law, I would say that they fall well within the provisional standard of the Mersey & Irwell Commission, containing less than 0.14 parts of albuminoid ammonia in 100 000 parts, and consuming less than 1.4 parts oxygen. As to the processes themselves meeting the requirements of the law, I can best answer by saying that in England, in order to receive authority for loans required to cover the cost of construction of new sewage works, towns must submit their plans to the Local Government Board for approval. As to bacterial filters. this board requires that contact beds receiving septic tank or chemically treated sewage must be able to deal with three times the ordinary dry-weather flow; and, further, that the plans must also provide an extra area of land, the extent to be at least one acre' for every thousand persons in the area provided with sewers. This extra land area is considered by the great majority of English sanitary engineers as a very conservative and unnecessary requirement, and they hope and believe that this condition will be changed in the near future. It should also be said that there are ways of obtaining money for the building of sewage works without obtaining the direct approval of the plans for purification by the Local Government Board; and, although it is more expensive, money has thus been obtained by certain towns.

DESCRIPTION OF EXPERIMENTAL FILTER PLANT AT PITTSBURGH, AND RESULTS OF EXPERIMENTS.

BY MORRIS KNOWLES, C.E., ASSISTANT ENGINEER-IN-CHARGE, TESTING STATION, IMPROVEMENT AND FILTRATION OF THE WATER SUPPLY, PHILADELPHIA, PA.; FORMERLY RESIDENT ENGINEER, FILTRATION COMMISSION, PITTSBURGH, PA.

[*Presented September 19, 1900.*]

GENERAL.

The city of Pittsburgh has a population of about 320 000, of which about 235 000 people are supplied with water by the municipal works, which pump from the Allegheny River. The remaining 85 000 are supplied by private companies, and almost all of the water for these people is pumped from the Monongahela River. We are interested at this time in the supply from the Allegheny. The water of this river, as regards turbidity, may be said to be midway between that of the streams of New England and of the Ohio and Mississippi valleys. It is occasionally very muddy, with large quantities of fine silt and clay. It is also polluted by sewage from many cities, towns, and mining villages, together with considerable mine drainage at times.

In June, 1896, the City Councils authorized the appointment of a Filtration Commission; to be composed of the mayor, the presidents of the councils, and eight representative citizens, two of whom were to be physicians. This commission, to quote the substance of the resolution, was to investigate the character of the present water supply, the effect of filtration, the advisability of establishing a filtration plant, and furnish an estimate of the cost of constructing and maintaining the same; also to investigate the feasibility and advisability of seeking other sources of supply.

Mr. Robert Pitcairn, general agent of the Pennsylvania Railroad, was chairman of the commission, and Mr. Allen Hazen, of New York City, was consulting engineer. Dr. Walther Riddle, of Pittsburgh, had charge of all chemical analyses, which were made in the private laboratory of Coster & Riddle. Mr. William R. Copeland,

FIG. 1.—PITTSBURGH WATER WORKS. BRILLIANT PUMPING STATION AND EXPERIMENTAL FILTER PLANT.

FIG. 2.—EXPERIMENTAL FILTER PLANT. SAND FILTERS AND FILTER BUILDING.

formerly of the Experiment Station of the Massachusetts State Board of Health, at Lawrence, Mass., had charge of the bacteriological laboratory, located at the filter plant. He was also in direct charge of the operation of the experimental filters.

It is proposed in this paper to confine our attention to that portion of the investigations which was carried on at the experimental filter plant; to present a short description of the apparatus used, with views of some interesting details of the same; and to briefly summarize some of the results obtained.*

Preparations were made in May, 1897, for beginning experiments with various types of filters, and on July 23 the sand filters were placed in operation; on January 14, 1898, the mechanical filters were started. The tile filters were first started November 25, 1897, and again, after two months of idleness, on June 12, 1898. The experiments were officially closed September 1, 1898, and the report of the commission was transmitted to councils in January, 1899.

DESCRIPTION.

The experimental filter plant was located at the pumping station of the municipal water works, at Brilliant Station, on the Allegheny Valley Railway, about six miles from the City Hall. Fig. 1 shows the general arrangement, and Plate I gives some views of the plant. Plate I, Fig. 1, was taken from the north bank of the river, showing the filters and building at the extreme right. Plate I, Fig. 2, shows the settling basin and two sand filters in front of the filter building, and the elevated location of Highland Reservoir No. 1 in the background.

The plant consisted of two sand filter basins, also a settling basin of about the area of both; a filter building, in which were located the measuring vault of the sand filters, the mechanical and tile filters, the filtered water tank, the wash-water pumps and other machinery, and also the experimental boilers. Water was supplied to the plant from a large force main in the yard, and was thus of about the same character as the river water, and varied nearly as rapidly as that in the river.

* A report upon the whole subject, together with a more complete description of the experimental work and a discussion of the results, will be found in the Report of Filtration Commission, Pittsburgh, 1899. The present paper also contains the results obtained with the experimental sand filters to January, 1900.

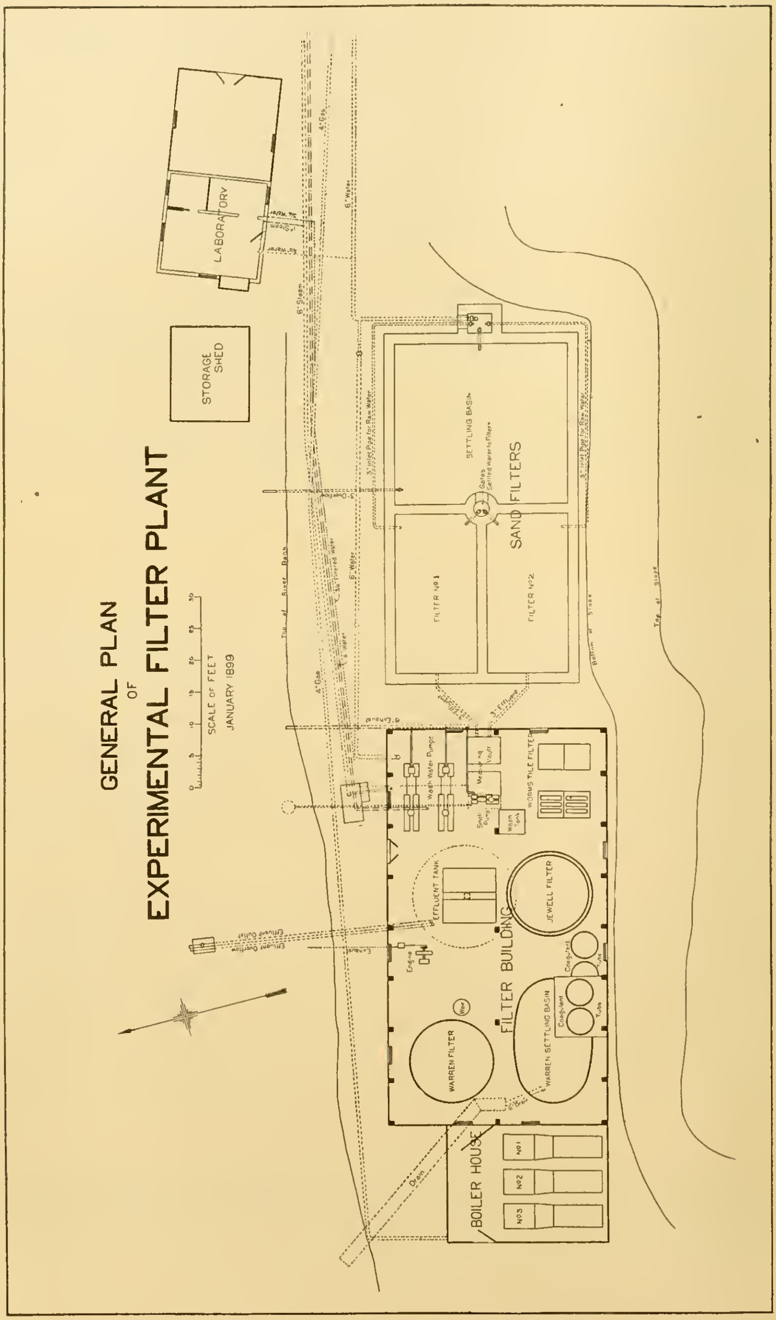
GENERAL PLAN
OF
EXPERIMENTAL FILTER PLANT
SCALE OF FEET
JANUARY 1899
LABORATORY
STORAGE SHED
SETTLING BASIN
SAND FILTERS
FILTER No 1
FILTER No 2
EFFLUENT TANK
JEWELL FILTER
FILTER BUILDING
WARREN FILTER
WARREN SETTLING BASIN
BOILER HOUSE
No 1
No 2
No 3
Top of River Bank
Bottom of Slope
Top of Slope

FIG. 1.

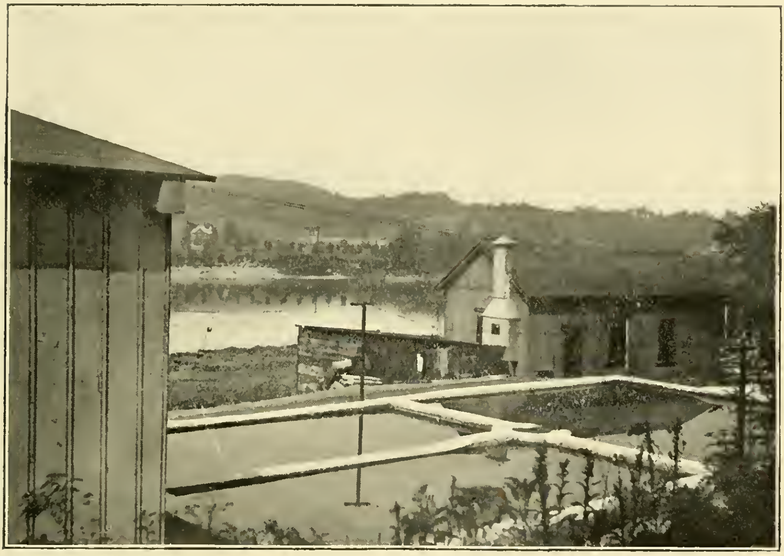

FIG. 1.—SAND FILTERS AND SETTLING BASIN.

FIG. 2.—SAND FILTER. METHOD OF SCRAPING.

SAND FILTERS.

Description. A plan and vertical section of the two sand filters are shown in Fig. 2, and a view of them is given on Plate II, Fig. 1. The entire structure — that is, walls and bottom — was built of concrete, but the filters were not covered in any way. The settling basin had a capacity of about 33 800 gallons, which, if complete displacement were realized, would have allowed twenty-four hours' sedimentation when one filter only was supplied with settled water. It is believed, however, that changes from inlet to outlet were accomplished in about two thirds of this time.

The under-drains were of vitrified pipes, four inches in diameter. Broken stone and gravel, to a depth of six inches, were placed on the concrete bottom and over the pipes. The layers of under-draining material were as follows: Three inches of broken stone of about 3 inches to $2\frac{1}{2}$ inches in size, which was covered with screenings or somewhat smaller broken chips, to close the larger interstices on top; $1\frac{3}{4}$ inches of clean river gravel of about $\frac{3}{4}$ inch to $\frac{5}{16}$ inch in size; $1\frac{1}{4}$ inches of clean river gravel which had been passed through a $\frac{5}{16}$-inch screen.

Allegheny River sand, which was deposited loosely in six layers for a depth of five feet, completed the beds. After it had settled in water for a few days the thickness had diminished to 4.2 feet, which was the amount in place at the beginning of the experiments. An average of 1.2 feet was removed during the thirteen months of operation. The average area of the sand surface was 0.0065 acre during the experiments, being about twelve square feet less at the close than at the beginning, owing to the batter of the walls. Plate II, Fig. 2, shows the method of scraping and the care taken by the attendant, by using sandals, not to make indentations in the sand surface. The average composition of the sand used may be seen in the following table: —

Results of Analyses of Sands used in the Sand Filters.

Source of Sample.	Effective Size. m.m.	Uniformity Coefficient.	Parts by Weight. Iron and Aluminum Oxides.	Calcium Carbonate.	Silicates and Insoluble Matter.
Filter No. 1 . .	0.30	2.0	0.98	1.32	97.70
Filter No. 2 . .	0.31	2.0	0.96	1.35	97.69

Apparatus. The effluent pipes were brought side by side into a small vault in the filter building, where the necessary devices were

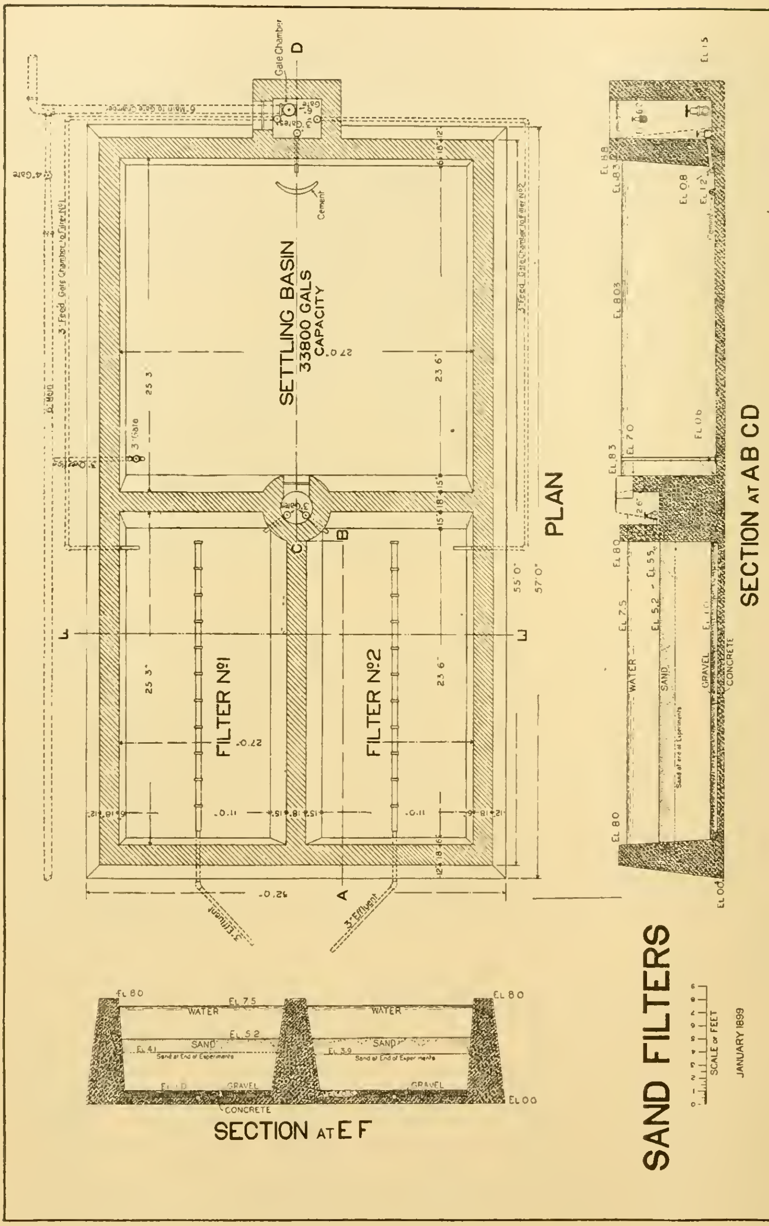
SETTLING BASIN
33800 GALS
CAPACITY
FILTER No. 1
FILTER No. 2
PLAN
SECTION AT AB CD
SECTION AT E F
SAND FILTERS
SCALE OF FEET
JANUARY 1899

FIG. 2.

placed for regulating and registering the rate of filtration. Meters were found unreliable on account of the amount of air in the water. Orifice indicators were therefore employed, which had the additional advantage of indicating the rate of filtration at the instant of observation. On Plate III, Fig. 1, will be seen two views of one of these indicators. Ten standard orifices were drilled in the one-eighth inch brass bottoms of copper cans, twelve inches in diameter and of the same depth. The water entered the side of the indicator and passed through a screen to prevent cross currents. On one side of the indicator there was a glass slide upon which a scale was fastened. The scale was graduated to read upon one edge in "Gallons per Orifice, Daily," and upon the other in "Million Gallons per Acre, per Orifice, Daily."

The attendant was instructed to keep the water at the half-million rate mark as nearly as possible, so that half the number of orifices open corresponded approximately to the rate of filtration. Orifices not in use were closed with rubber stoppers. The loss of head was read downward directly upon a movable scale board, the zero of which was changed frequently during the day to agree with the level of the surface of the water outside on the filter basin. Various rates of filtration were used between two million and five million gallons per acre daily, with both settled water and that which came directly from the river without any appreciable rest.

The turbidity of the river and settled waters was determined by observing the distance below the surface at which a platinum wire could be seen in the water. The record was expressed as the reciprocal of the depth, in inches, at which the wire just disappeared from view. The turbidity of the effluents was observed by comparison, in gallon bottles, with standards of known turbidity, which were made from a stock silver nitrate solution, precipitated in distilled water with sodium chloride. The relation between the two standards was determined approximately, and all results expressed in terms of the first-mentioned method.

Results. The average quantitative and bacterial results secured with the sand filters during the thirteen months are given in the following table, No. 1. The figures given in this and subsequent tables are, in some instances, slightly different from those found in the Report of the Filtration Commission. This is due to rounding up and using even figures.

Leaks and Cold Weather. In partial explanation of some of the

TABLE NO. 1.—AVERAGE OF DAILY RESULTS WITH SAND FILTERS, BY MONTHS.

MONTHS.	Hours in Operation per Day.		Rate of Filtration, Million Gallons per Acre Daily.		Turbidity.				Bacteria per Cubic Centimeter.				Percentage of Bacteria Removed.	
					Raw Water.	Settled Water.	Effluents.		Raw Water.	Settled Water.	Effluents.			
	No. 1.	No. 2.	No. 1.	No. 2.			No. 1.	No. 2.			No. 1.	No. 2.	No. 1.	No. 2.
1897.														
August	23.8	22.9	2.40	2.30	0.18	0.13	—	—	2 090	1 280	46	42	97.80	97.99
September . . .	24.0	24.0	2.98	3.00	0.05	0.04	—	—	2 480	1 230	16	16	99.35	99.35
October	23.3	23.7	2.90	2.95	0.03	0.03	—	—	72 900	39 200	32	32	99.96	99.96
November . . .	21.5	20.1	2 64	2.42	0.26	0.18	—	—	25 200	29 900	346	632	98.63	97.49
December . . .	22.4	23.5	2.76	2.46	0.19	0.14	—	—	14 400	14 900	163	225	98.87	98.44
1898.														
January	22.5	22.8	2.77	1.87	0.27	0.15	—	—	15 300	13 800	334	310	97.82	97.98
February	23.5	23.4	2.93	2.27	0.15	0.10	.011	.011	9 430	12 000	266	275	97.18	97.08
March	23.5	22.7	2.95	2.83	0.28	0.17	.013	.017	11 700	12 300	71	332	99.40	97.17
April	23.4	23.5	2.95	2.99	0.08	0.08	.003	.005	5 010	4 930	33	91	99.34	98.18
May	23.6	23.6	2.93	2.95	0.19	0.12	.012	.011	10 800	6 770	110	99	98.98	99.08
June	22.8	22.9	2.83	2.85	0.19	0.11	.011	.012	11 100	5 930	135	72	98.78	99.35
July	23.5	23.6	2.94	4.97	0.11	0.07	.003	.003	16 800	13 000	74	89	99.56	99.47
August	22.8	23.1	2.85	4.82	0.36	0.25	.008	.017	15 100	10 250	51	82	99.66	99.46
Average, 13 months,	23.1	23.1	2.83	2.98	0.18	0.12	—	—	16 400	12 800	128	176	99.22	98.93

NOTES.—Filter No. 1 was operated with settled water all the time, except for occasional days.

Filter No. 2 was operated with water not settled, but applied directly from the river, from July 24 to December 19, 1897, and from February 20 to June 30, 1898; and at other times with settled water.

FIG. 1. — SAND FILTERS. ORIFICE INDICATORS.

FIG. 2. — SAND FILTERS. REMOVAL OF ASBESTOS FILM.

high bacterial results obtained during the cold weather, attention should be called to the cracks in the wall between the settling basin and the filters, the effect of which apparently first showed in the effluents about the middle of November, 1897. At this time it was endeavored to repair these cracks by closing them on the settling basin side, and it was then believed that this attempt was practically successful. In June, 1898, however, a small leak was again noticed; this time a small trough was built out under the opening, so that the water was compelled to pass out into the sand, instead of down along the wall. After this no trouble was noticed. Danger from cracks of this kind is lessened by placing the filter sand on the bottom for a short distance around the walls, instead of having the gravel and broken stone up close. But much safer also is that construction which provides for a settling basin some distance from the filters, so that there is something better than a concrete wall between polluted and purified water. It is probable, however, that the lower bacterial efficiency in the winter was due in some degree to the disturbing influences of low temperature, especially upon the sand surface when exposed for scraping, upon these open and unprotected filters.

Recent Data. Through the kindness of the director of public works, Mr. E. M. Bigelow, of the superintendent of the Bureau of Water, Mr. A. B. Shepherd, and of Mr. William R. Copeland, now bacteriologist-in-charge, the writer is enabled to present, in Table No. 1A, a summary of results obtained by the Bureau of Water since September, 1898. The results for the winter months are in line with those in Table No. 1, and show markedly the influence of the cold weather.

In June, 1899, the upper foot (approximately) of the sand then remaining in the filters was removed, and new sand was placed in them to a depth of three feet; then about nine inches of the old material was replaced, bringing the sand surface about to the original grade. For this reason the average results for the first six days of June, 1899, are reported separately from those for the last nineteen days. However, the average for the year 1899 was obtained by using an average for June, giving the proper weight to the duration in time of each group of results.

Five baffle walls were used after August 23, 1899, in one half of the settling basin, which caused the water applied to Filter No. 2 to travel in a tortuous course, horizontally, and thus gave a more complete displacement.

TABLE NO. 1A. — AVERAGE OF DAILY RESULTS WITH SAND FILTERS, BY MONTHS.

(AFTER AUGUST, 1898.)

MONTHS.	Hours in Operation per Day.		Rate of Filtration, Million Gallons per Acre Daily.		Turbidity.				Bacteria per Cubic Centimeter.				Percentage of Bacteria Removed.	
					Raw Water.	Settled Water.	Effluents.		Raw Water.	Settled Water.	Effluents.			
	No. 1	No. 2.	No. 1.	No. 2.			No. 1.	No. 2.			No. 1.	No. 2.	No. 1.	No. 2.
1898.														
September	23.4	22.1	3.04	4.67	0.04	0.03	.004	.006	18 100	17 500	54	120	99.70	99.34
October	23.8	21.9	2.90	4.62	0.11	0.09	.003	.003	35 200	34 600	100	140	99.72	99.60
November	23.7	20.7	3.09	2.61	0.10	0.10	.010	.009	15 700	12 000	190	325	98.79	97.93
December	22.0	22.7	2.85	2.73	0.11	0.08	.005	.006	22 400	19 400	940	850	95.80	96.21
Average, 1898	23.2	22.7	2.92	3.35	0.17	0.11	.008	.009	15 700	13 600	197	233	98.75	98.58
1899.														
January	24.0	23.3	3.06	3.01	0.15	0.13	.016	.012	29 700	38 300	506	360	98.30	98.79
February	22.4	23.4	2.97	3.10	0.15	0.10	.008	.007	12 600	16 200	380	340	96.99	97.31
March	23.3	23.4	3.15	2.95	0.21	0.18	.021	.021	17 400	16 800	179	282	98.97	98.38
April	23.3	23.3	3.17	3.08	0.10	0.09	.016	.012	7 000	7 110	65	64	99.07	99.09
May	22.4	23.5	2.99	3.12	0.14	0.13	.008	.012	10 000	9 810	114	128	98.86	98.72
June, 6 days	23.2	24.0	3.07	3.12	0.18	0.09	.012	.010	5 730	3 840	79	106	98.62	98.15
June, 19 days	24.0	23.9	2.02	2.00	0.16	0.13	.016	.016	13 600	4 900	1 500	1 010	89.00	92.60
July	22.2	22.8	2.40	2.44	0.20	0.18	.011	.015	8 250	4 640	218	128	97.36	98.45
August	23.2	23.4	2.92	2.89	0.27	* 0.24 0.17	.015	.016	20 400	* 14 900 18 700	56	86	99.73	99.58
September	23.2	23.2	2.93	2.94	0.16	* 0.15 0.13	.010	.009	23 600	* 15 800 16 100	56	44	99.76	99.81
October	23.2	23.3	2.97	2.97	0.04	* 0.04 0.04	.002	.002	41 500	* 29 900 26 500	48	45	99.88	99.89
November	21.7	21.7	2.68	2.64	0.15	* 0.14 0.13	.006	.005	13 500	* 10 900 16 200	405	79	97.00	99.41
December	23.0	22.6	2.64	2.79	0.18	* 0.17 0.14	.012	.013	15 000	* 13 300 12 400	121	165	99.19	98.90
Average, 1899	23.0	23.1	2.85	2.84	0.16	0.13	.012	.012	17 600	15 400	272	207	98.45	98.82
January, 1900	21.7	21.1	2.44	2.34	0.19	* 0.14 0.13	.012	.014	22 100	* 27 800 21 400	463	535	97.90	97.58

NOTES. — Settled water was applied to both filters all the time, except for occasional days.
Averages of both periods in June, and, for records starred, the average of both results, were used in computing yearly averages.
* First result given where starred refers to water applied to Filter No. 1, and second result to that applied to Filter No. 2.

Asbestos pulp was used on the surface of Filter No. 2 in different quantities, from October 27 to November 12, 1898. From November 2 to December 13, 1898, sulphate of alumina was added to the applied water, as it entered the settling basin, at rates varying from one quarter of a grain to one grain per gallon. Neither of these special experiments was productive of conclusive evidence, as the time of trial was limited, and the facts are recorded here solely in order that the full history to accompany Table No. 1A may be given. Plate III, Fig. 2, shows how the asbestos pulp may be rolled up like a carpet when dried to the proper degree.

Periods between Scrapings. The following tables, No. 2 and No. 2A, contain the results of the runs between scrapings, the first until September, 1898, and the second from that time to January, 1900. The results for Filter No. 1, in Table No. 2, differ slightly from the summaries given in the Report of the Filtration Commission, as the data has been entirely recalculated from the original records, to give the result at the exact time that the loss of head reached four feet.

Not all the periods have been included in Table No. 2A. When special tests with asbestos were conducted and when, for experimental purposes, very small depths of sand were removed at a scraping, which created for the next run a large initial loss of head, greater than one foot, some of the results are omitted from the tables.

In Tables No. 2 and No. 2A, it will be noticed that there appears to be some relation between the length of period, or quantity filtered between scrapings, and the average turbidity for the period. In general, the more turbid the water, the less the length of the period and the less the quantity filtered, but the relation is not an exact one. On the diagram, Fig. 3, the results in Tables No. 2 and No. 2A have been plotted, using the quantity filtered as ordinates, and as abscissæ the square of the average turbidity during the period divided by the average rate of filtration. It will be seen that many points are some distance away from the average line, yet there does seem to be some general relation.

It may be that the storage of suspended matter in the sand, as evidenced by the turbidity of the effluent long after the muddy water has passed by, affects the length of the period to some degree. The length of the period is also undoubtedly influenced somewhat by the variation in the temperature of the applied water; the low temperature in winter causing a greater loss of head than in the warmer

TABLE NO. 2.—QUANTITATIVE RESULTS OBTAINED DURING EACH PERIOD OF OPERATION WITH THE SAND FILTERS, THE LOSS OF HEAD BEING LIMITED TO FOUR FEET.

Number of Period.		Number of Days.		Average Turbidity.				Quantity Filtered, Million Gallons per Acre.		Depth of Sand in Feet Removed at Scraping.	
				Applied Water.		Effluent.					
No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
1	2	22.8	14.7	0.13	0.27	—	—	44.6	30.8	0.04	0.04
2	3	45.7	37.1	0.06	0.06	—	—	135.9	111.3	0.06	0.04
3	4	32.9	37.0	0.03	0.04	—	—	98.8	111.8	0.05	0.06
4	5	17.9	4.2	0.20	0.54	—	—	53.1	12.1	0.05	0.07
—	6	—	11.0	—	0.24	—	—	—	32.7	—	0.09
5	7	18.2	21.4	0.15	0.16	—	—	54.1	51.0	0.13	0.05
6	8	12.1	17.0	0.07	0.18	—	—	36.0	34.1	0.03	0.04
7	9	12.1	9.4	0.21	0.14	—	0.022	35.9	18.6	0.05	0.10
8	10	11.2	29.1	0.10	0.10	0.012	0.011	33.1	69.1	0.10	0.06
9	11	30.5	18.6	0.10	0.13	0.012	0.009	91.3	56.8	0.07	0.06
10	12	26.4	4.2	0.21	0.98	0.014	0.046	79.8	12.3	0.12	0.13
—	13	—	14.4	—	0.14	—	0.013	—	43.8	—	0.07
11	14	32.8	26.4	0.06	0.08	0.002	0.002	99.2	81.1	0.07	0.07
12	15	33.3	23.8	0.10	0.21	0.014	0.015	100.2	72.1	0.07	0.10
—	16	—	16.1	—	0.22	—	0.008	—	48.4	—	0.11
13	17	30.0	17.2	0.12	0.15	0.007	0.013	90.4	69.3	0.09	0.06
14	18	30.8	22.5	0.21	0.07	0.003	0.001	92.8	114.4	0.13	0.07
—	19	—	17.7	—	0.28	—	0.012	—	89.5	—	0.12
Average		25.5	19.0	0.12	0.15			74.7	58.8	0.08	0.07

TABLE NO. 2A. — QUANTITATIVE RESULTS OBTAINED DURING EACH PERIOD OF OPERATION WITH THE SAND FILTERS, THE LOSS OF HEAD BEING LIMITED TO FOUR FEET.

(AFTER AUGUST, 1898.)

Number of Period.		Number of Days.		Average Turbidity. Applied Water.		Average Turbidity. Effluent.		Quantity Filtered, Million Gallons per Acre.		Depth of Sand in Feet Removed at Scraping.	
No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
16	20	29.8	22.3	0.05	0.09	0.006	0.018	72.3	112.3	0.05	0.09
17	21	30.6	33.8	0.06	0.03	0.001	0.002	71.7	179.1	0.09	0.09
18	—	19.8	—	0.10	—	0.014	—	64.0	—	0.07	—
19	27	10.2	13.4	0.05	0.04	0.004	0.000	33.9	41.6	0.10	0.24
20	28	16.2	13.4	0.04	0.09	0.000	0.002	51.2	41.2	0.09	0.09
21	—	9.9	—	0.20	—	0.016	—	30.7	—	0.15	—
22	29	34.1	28.1	0.12	0.14	0.013	0.014	100.6	86.6	0.11	0.17
23	30	12.3	27.3	0.05	0.06	0.005	0.006	39.4	84.1	0.09	0.08
24	31	30.1	30.2	0.20	0.21	0.022	0.019	96.3	94.0	0.24	0.12
25	32	31.3	36.1	0.11	0.12	0.020	0.016	98.5	109.7	0.09	0.06
26	33	23.2	38.2	0.04	0.10	0.005	0.011	76.3	121.8	0.04	0.06
27	—	15.0	—	0.11	—	0.011	—	18.4	—	0.04	—
28	34	19.4	19.1	0.16	0.16	0.012	0.015	38.3	37.8	0.05	0.06
29	35	17.0	18.0	0.14	0.17	0.012	0.016	48.0	48.9	0.19	0.08
30	36	23.0	23.0	0.21	0.23	0.016	0.019	70.1	73.7	0.06	0.08
31	37	23.0	28.0	0.22	0.12	0.012	0.010	69.7	82.6	0.11	0.10
32	38	38.0	36.5	0.06	0.05	0.004	0.003	118.2	107.4	0.06	0.04
33	39	10.0	6.0	0.12	0.13	0.002	0.001	29.4	20.9	0.03	0.02
34	40	9.6	10.0	0.09	0.09	0.007	0.004	31.0	30.6	0.05	0.05
35	41	9.0	11.0	0.13	0.12	0.007	0.007	26.4	32.5	0.04	0.05
36	42	8.2	10.5	0.06	0.06	0.008	0.008	23.0	26.4	0.03	0.04
37	43	5.2	3.5	0.25	0.33	0.007	0.017	14.3	9.5	0.08	0.04
Average		22.5	26.3	0.11	0.11	0.010	0.010	64.6	87.2	0.10	0.10

NOTES. — During periods 22-26, inclusive, for filter No. 2, asbestos was used on the surface.

For the last five periods of each filter, small depths of sand were removed at scrapings, which caused an initial loss of head greater than one foot, and decreased the lengths of the periods. The results of these periods were not used in computing the averages.

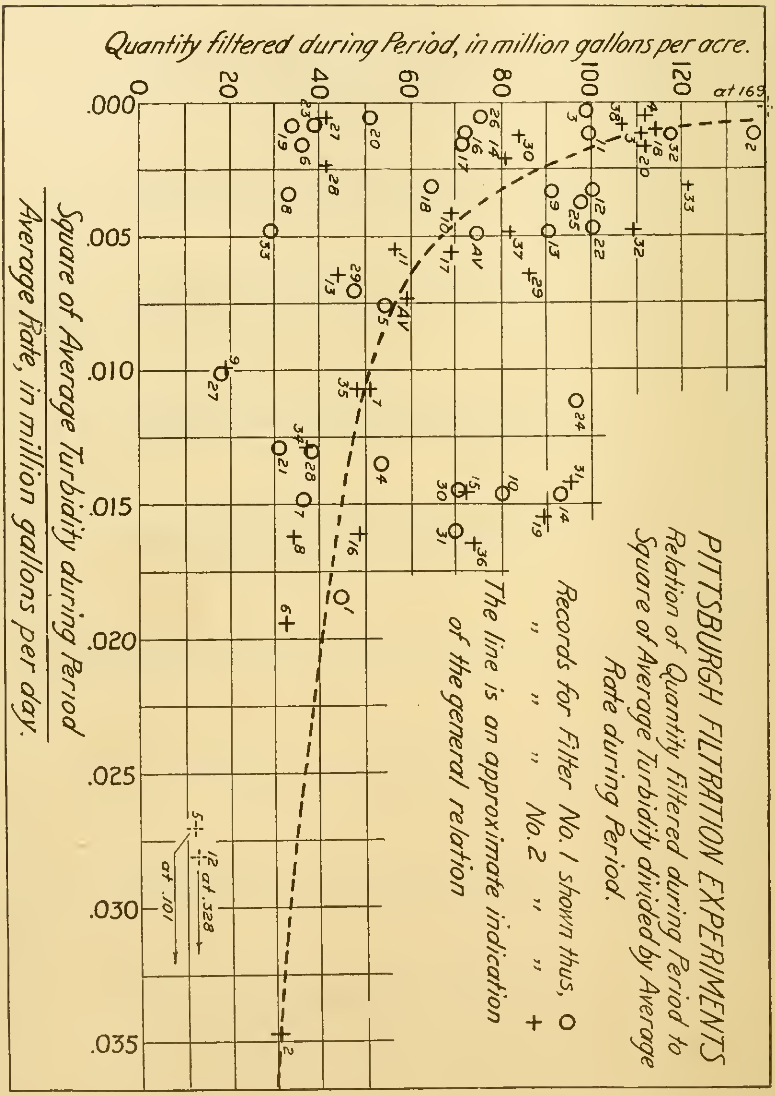
PITTSBURGH FILTRATION EXPERIMENTS
Relation of Quantity Filtered during Period to Square of Average Turbidity divided by Average Rate during Period.
Records for Filter No. 1 shown thus, O
" " " No. 2 " " +
The line is an approximate indication of the general relation
Quantity filtered during Period, in million gallons per acre.
0
20
40
60
80
100
120
at 169
.000
.005
.010
.015
.020
.025
.030
.035
at .328
at .101
Square of Average Turbidity during Period
Average Rate, in million gallons per day.

FIG. 3.

weather, to filter the same quantity. It is probable, however, that these factors are obscured by the errors in determining the effect of the water upon the filters, in regard to depositing a clogging layer, but, more than anything else, the diagram teaches us that a more accurate method of observing turbidity is needed.

The question of this relation is an interesting and even an important one, for if, by continuous and systematic observations of the turbidity of a source of supply, the probable quantity of water that will be filtered between scrapings can be determined, the largest item of the cost of maintenance of slow sand filters may be accurately estimated without waiting for the actual trial of filters.

TABLE NO. 3.—AVERAGE RESULTS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM THE ALLEGHENY RIVER AND SAND FILTERS DURING THE THIRTEEN MONTHS ENDING AUGUST 31, 1898.

(Parts per 100 000.)

CONSTITUENTS.	River Water.	Outlet from Settling Basin.	Effluents.		Percentage of Constituents Removed.	
			No. 1.	No. 2.	No. 1.	No. 2.
Color	0.29	0.27	0.09	0.09	69	69
Nitrogen as						
Albuminoid Ammonia	0.0116	0.0108	0.0063	0.0064	46	45
Free Ammonia	0.0019	0.0019	0.0016	0.0016	16	16
Nitrites	0.0000	0.0000	0.0000	0.0000	. .	. .
Nitrates	0.0684	0.0641	0.0715	0.0647	– 5	5
Chlorine	2.19	2.08	2.06	2.02	6	8
Total Solids	15.9	13.1	12.1	12.1	24	24
Suspended Matter	4.2	1.3	0.0	0.0	100	100
Total Hardness	3.58	3.69	4.72	4.83	– 32	– 35
Alkalinity	2.89	3.07	4.13	4.22	– 43	– 46
Sulphuric Acid	1.44	1.38	1.44	1.44	. .	. .
Iron	0.052	0.060	0.016	0.018	69	65

Chemical Results. Table No. 3 gives the average results, for the whole period of the test, of the chemical analyses of samples of water collected from the Allegheny River, from the outlet of the settling basin, and of the sand filter effluents, together with the percentage of chemical constituents removed. Tables 12A to 12E, at the end of this paper, contain the monthly averages of the results of the chemical analyses and average summaries for different periods.

WARREN FILTER.

This filter was located in the westerly portion of the filter building. Fig. 4 shows a plan and Fig. 5 an elevation. The system consisted of a settling basin, having baffle walls, and a circular tank, or filter proper, which contained the filter sand, agitating, washing, and regulating devices.

Settling Basin. The capacity of the settling basin was about 11 200 gallons, which gave, if complete displacement were accomplished, a period of about fifty minutes for the water to pass from one end to the other, when the filter was operated at a rate of 120 million gallons per acre daily. Just before the water entered the settling basin it was measured by a meter and then at the entrance was controlled by a butterfly valve, which was attached to a float in the basin. Next, the water passed through a propeller which operated the revolving coagulant pump, or tympanum, on the platform above.

Coagulant. The solution of coagulant was introduced as the water passed the propeller. The average composition of the sulphate of alumina, which was the coagulant used in both Warren and Jewell filters, was: —

	Parts by Weight.
Alumina oxide, soluble in water	17.18
Iron oxide	0.00
Suplhuric acid	38.66
Material insoluble in water	0.24

The coagulant solution was dissolved in two tubs placed on top of the settling basin, and allowed to flow first from one, then from the other, into the tank in which the tympanum was placed. The inner end of each arm of this pump was connected to one of a series of six tubes placed in the hub and parallel to the shaft. As the pump revolved, each arm in turn was filled; as the arm became elevated, the solution passed down into the hub, out into a lead cup on the side of the tank, and thence to the settling basin below. A view of the coagulant tubs with tank and tympanum is shown on Plate IV, Fig. 1, and the exit of pipe in the settling basin in Fig. 2 on the same plate.

The level of the solution in the pump tank was kept as constant as possible by rubber float valves. It was found, however, that

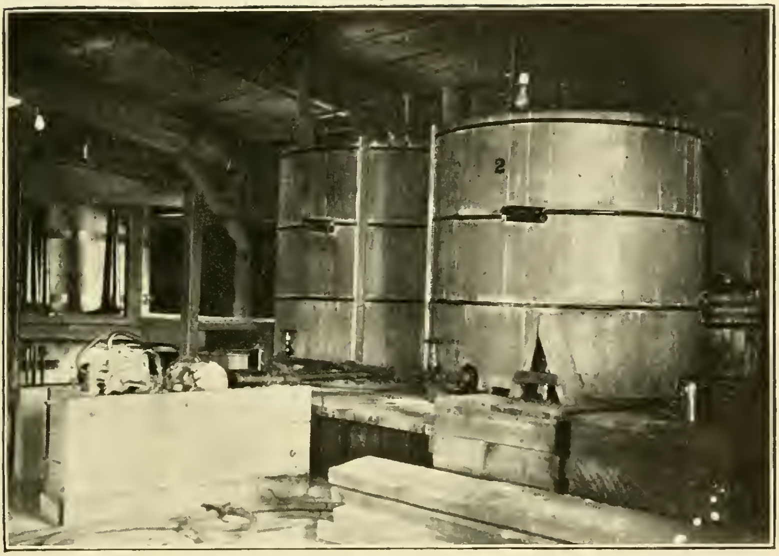

FIG. 1.—WARREN FILTER. COAGULANT TUBS AND CHEMICAL PUMP.

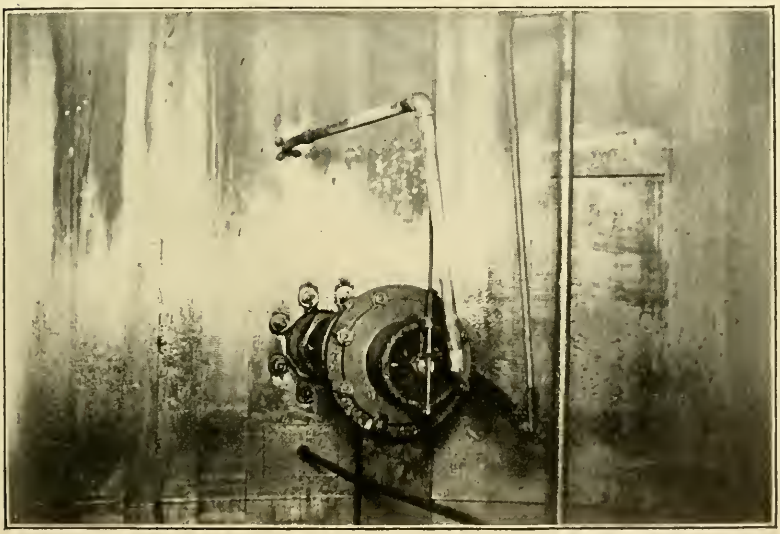

FIG. 2.—WARREN FILTER. INLET TO SETTLING BASIN.

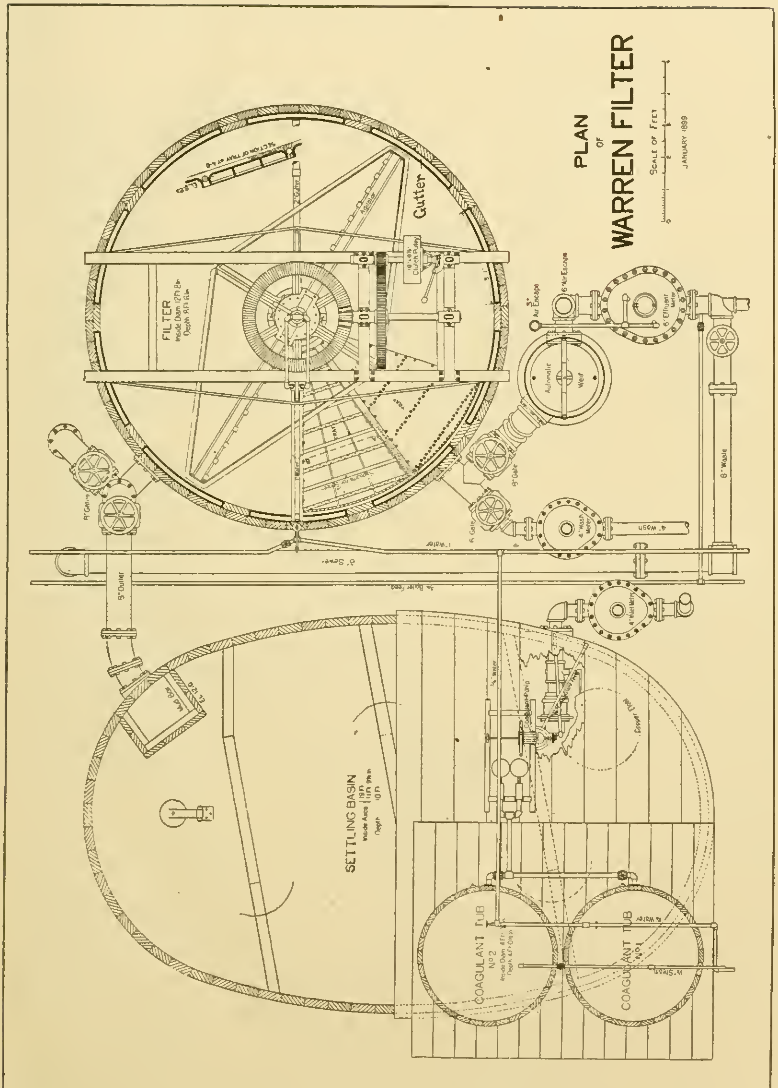
PLAN OF WARREN FILTER
SCALE OF FEET
JANUARY 1899
FILTER
SETTLING BASIN
COAGULANT TUB No 2
COAGULANT TUB No 1
Gutter
Automatic Weir
8" Waste
9" Outlet

FIG. 4.

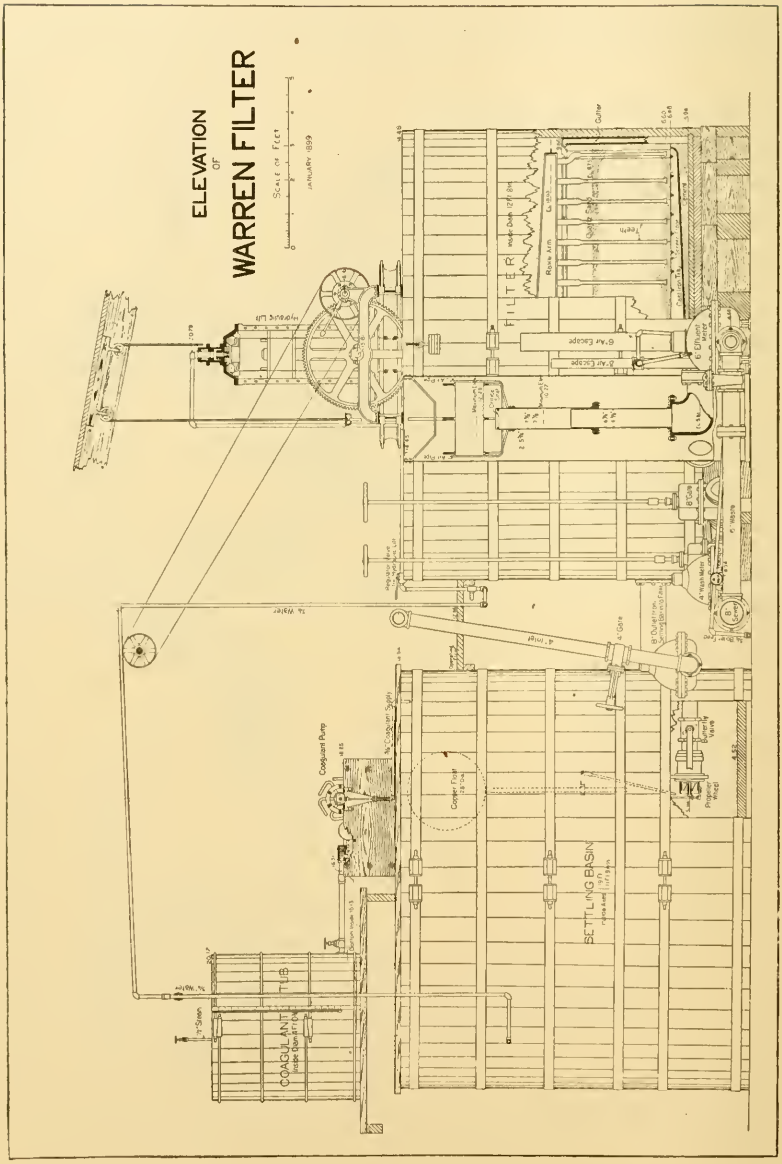
ELEVATION
OF
WARREN FILTER
JANUARY 1899
FILTER
SETTLING BASIN
COAGULANT TUB
Coagulant Pump

FIG. 5.

this method was not entirely satisfactory, as the valves frequently became clogged. Also, when a new solution was first used, the higher elevation of the liquid in the pump tank, due to the pressure from a full tub above, caused much more coagulant to be added to the applied water than when the solution in the upper tub had nearly run out. It was endeavored to remedy this by opening the valve from the coagulant storage tub a little only at the beginning and gradually increasing this opening as the tub became empty. Even

TABLE NO. 4.—VARIATIONS IN THE APPLICATIONS OF COAGULANT TO MECHANICAL FILTERS.

Number of Experiment.	Calendar Date of Experiment, 1898.	Name of Filter.	Amount of Sulphate of Alumina Used, in Grains per Gallon. For Duration of Thirty Minutes. Highest.	Lowest.	Average for Duration of Experiment.	Percentage of Variation from he Average. Highest.	Lowest
1	April 14	Warren	0.91	0.39	0.55	+ 66	- 29
2	,, 14	Jewell	0.53	0.26	0.34	+ 56	- 24
3	June 10	Warren	2.48	0.80	1.30	+ 91	- 38
4	,, 23	,,	3.96	0.66	2.19	+ 81	- 70
5	,, 23	Jewell	2.48	1.05	1.90	+ 31	- 45
6	August 12	Warren	3.86	0.91	1.57	+ 146	- 42
7	,, 12	Jewell	2.09	0.65	1.11	+ 88	- 41
Averages,			2.33	0.67	1.28	+ 82	- 48

with this care the rate of application of the coagulant solution was not constant.

Without quoting in detail the tables which are published in the report, the brief summary in Table No. 4 will show the nature and amount of this variation, both for the Warren and Jewell filters. It must be remembered, however, in studying this table, that it is more difficult to apply small quantities of a coagulating liquid in an accurate manner than it is to do similar work on a large scale.

Filter. The filter proper was composed of a circular tank with a sand area of 118 square feet. On the bottom, inside, there were placed radial iron troughs, set in concrete, which served as a sup-

port for a brass strainer floor, and also as collectors for the filtered water. From the bottom of the tank and connected directly with the inlet pipe, there was a central well which extended up through the filter floor, and above the sand surface. Attached to this well and between the collecting troughs, there were ten two-inch horizontal pipes, which were connected with vertical iron gutters, placed around the filter inside the staves.

The inlet water from the settling basin was distributed over the sand surface from the central well, and from the circumferential gutters. Plate V, Fig. 1, shows the collecting troughs, with ribs for supporting the screens, and Plate V, Fig. 2, shows the central well, circumferential gutters, and two-inch connecting pipes at the time the filter was being dismantled.

The sand used was crushed quartz, which was angular at first, but the sharp edges became rounded after some months of use. The effective size was 0.63 mm. and the uniformity coefficient was 1.1. The sand was 2.3 feet deep and rested directly on the brass strainer floor, which contained 292 900 holes, each being 0.024 inch in diameter.

Regulating Weir. After passing through the sand, the water was collected in the radial troughs, and from a central annular compartment passed to the chamber of the so-called automatic weir. The principle of this device was that of a changeable orifice plate in a sliding pipe attached to a large copper float, thus endeavoring to maintain approximately the same head upon the orifice. In fact, however, the quantities filtered were somewhat less before washing than immediately after. The extent of the variation will be seen, for some representative periods, in Table No. 5. This controlling weir was the cause of over-registration of the effluent meter, due to the presence of air needed to properly operate the weir. This error was as large as thirteen per cent. and varied in the beginning, but, by the application of air escape pipes at proper places between the weir and the meter, the error was reduced and maintained at a constant rate of four per cent.

Washing. Filtered water was furnished for washing by two duplex steam pumps, size 12 × 7 × 18 inches, which drew the water from a large effluent tank under the building. The wash-water was measured by a meter, then entered the filter by the effluent pipe, and passed up through the screens and sand in the opposite direction to that of the current of water when filtering. As the dirty water flooded above

FIG. 1. — WARREN FILTER. COLLECTING TROUGHS AND SCREEN SUPPORTS.

FIG. 2. — WARREN FILTER. DISMANTLED INTERIOR, SHOWING CENTRAL WELL, RADIAL TROUGHS, CIRCUMFERENTIAL GUTTERS, AND CONNECTING PIPES.

the sand, it overflowed down the central well and the circumferential gutters, and passed out through a waste pipe to the sewer.

Agitator. At the time of washing, the agitator was made to rotate through the sand at the rate of three turns to the minute, thus stirring the mass to the bottom. This device consisted of two horizon-

TABLE NO. 5.—VARIATIONS IN THE RATES OF FILTRATION WITH MECHANICAL FILTERS.

Number of Experiment.	Calendar Date of Experiment, 1898.	Name of Filter.	Quantity Filtered in Gallons.			Percentage of Variation.		
			For Duration of Thirty Minutes.		Average for Duration of Experiment.	From the Average.		Total between Extremes.
			Highest.	Lowest.		Highest.	Lowest.	
1	April 14	Warren	8 670	6 380	7 550	+ 15	- 15	30
2	,, 14	Jewell	6 420	5 210	5 740	+ 12	- 9	21
3	June 10	Warren	7 720	4 520	5 780	+ 34	- 22	56
4	,, 23	,,	7 110	5 360	6 330	+ 12	- 15	27
5	,, 23	Jewell	6 290	5 260	5 780	+ 9	- 9	18
6	August 12	Warren	9 260	5 170	7 360	+ 26	- 30	56
7	,, 12	Jewell	8 580	2 680	5 550	+ 55	- 52	107
Averages,			7 720	4 940	6 300	+ 23	- 22	45

tal arms, 180 degrees apart, connected to a central vertical shaft, the latter being turned by gearing driven from power, which in this case was furnished by a small engine on the floor. On each of the arms were nine teeth, which cleared the strainer bottom by 0.14 foot, when the agitator was in the lowest position. The device was raised and lowered by means of a hydraulic lift placed on top of the central shaft, the whole being supported upon I-beams, placed on top of the filter. Plate VI, Fig. 1, shows the gearing of agitating system and hydraulic lift on top of filter, and Plate VI, Fig. 2, shows the rakes extending down from the arms, just touching the sand surface.

JEWELL FILTER.

This filter was located in the central portion of the filter building. Fig. 6 shows a plan and Fig. 7 an elevation. The plant consisted of

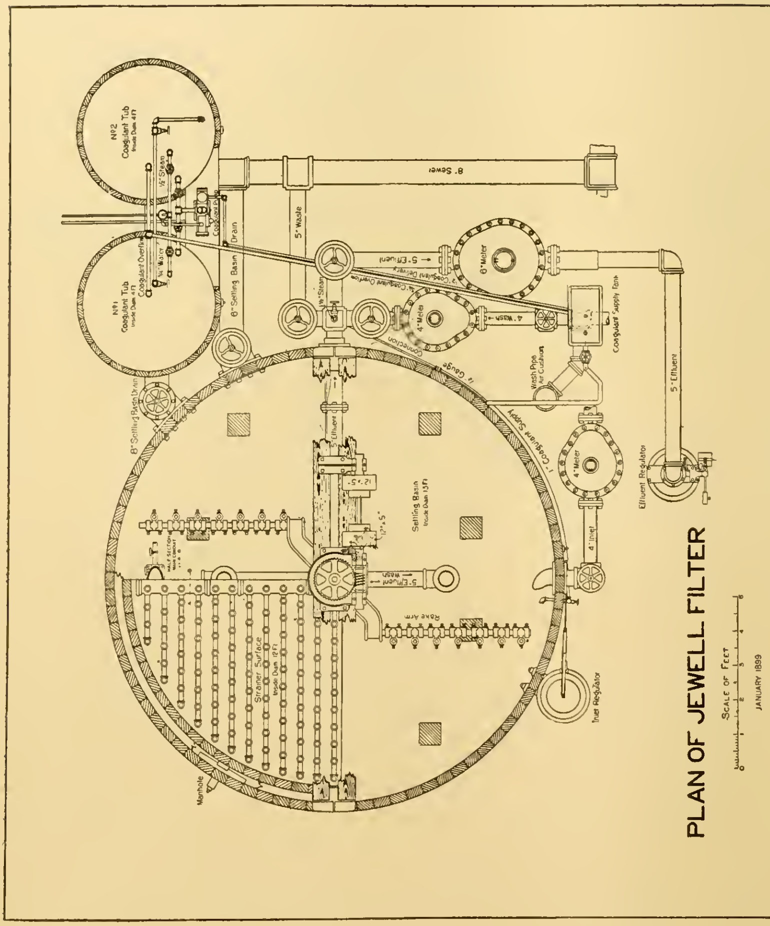
PLAN OF JEWELL FILTER
SCALE OF FEET
JANUARY 1899
No. 1 Coagulant Tub
No. 2 Coagulant Tub
8" Sewer
5" Waste
6" Meter
4" Meter
5" Effluent
Settling Basin
Strainer Surface
Rake Arm
Inlet Regulator
Effluent Regulator
Coagulant Supply Tank
Manhole
4" Inlet

FIG. 6.

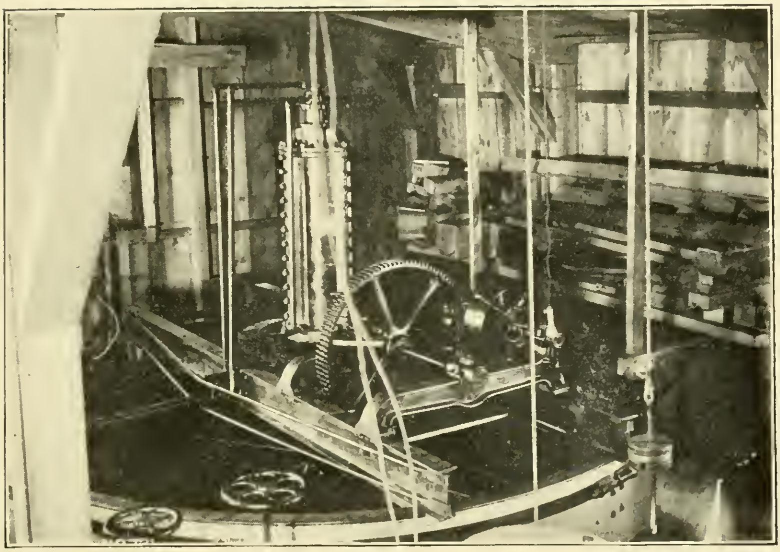

FIG. 1.—WARREN FILTER. HYDRAULIC LIFT AND AGITATOR GEARING.

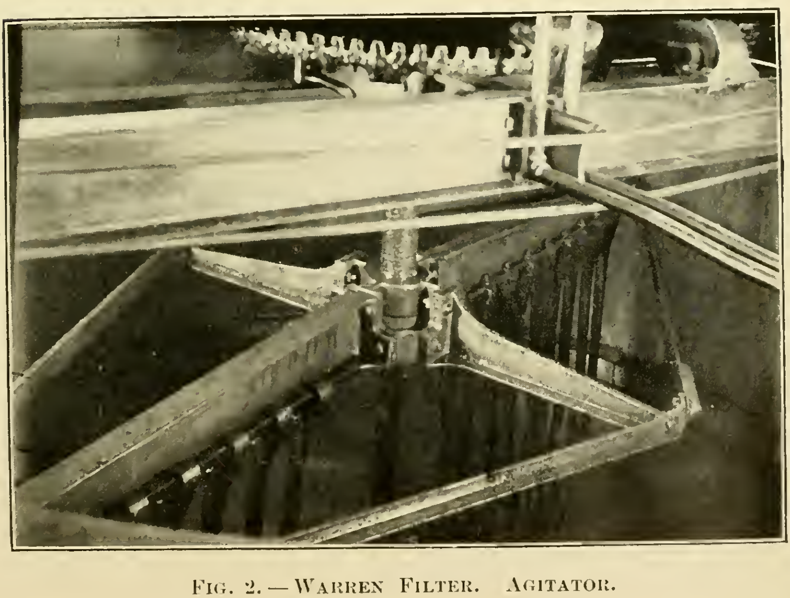

FIG. 2.—WARREN FILTER. AGITATOR.

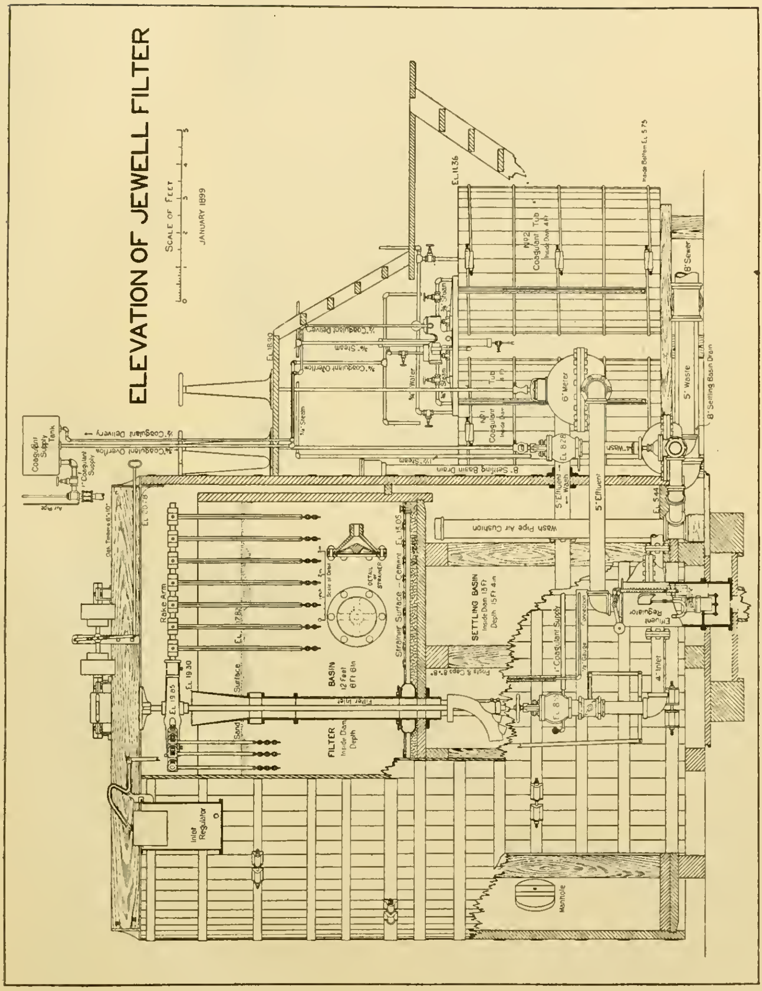
ELEVATION OF JEWELL FILTER
SCALE OF FEET
JANUARY 1899
Inlet Regulator
Rake Arm
SETTLING BASIN
Wash Pipe Air Cushion
6" Meter
Manhole
Effluent Regulator

FIG. 7.

a settling basin in the bottom portion of an outside tank, and an open filter in a smaller tank placed within and above the former.

Settling Basin. The capacity of the basin was about 6 600 gallons, which was equal to the flow for thirty-five minutes when the filter was operated at the rate of 105 000 000 gallons per acre daily. The water was admitted to the basin through a curved deflecting pipe, which gave it a whirling motion as it passed upward to the filter above. Plate VII, Fig. 1, shows the interior of the settling basin and the supports for the filter above.

Coagulant. The preparation of the coagulant was the same as for the Warren Filter. The solution was lifted by a small steam pump from either of the two tubs to a small tank above the filter, in which a constant head was maintained by pumping an excess, and allowing the surplus to run back to the original tub. This method aided somewhat, also, towards keeping the solution mixed in the tub. From the tank the solution passed through a standard orifice and pipe to the settling basin, which it entered near the place where the applied water passed in. Changes in the amount of the coagulant were made by changing the orifices. This method of application was somewhat more exact than that used with the Warren Filter, as the figures given in Table No. 4 indicate, but incrustation on the edges of the orifice changed the area and thus caused errors.

Filter. The filter proper was placed above the settling basin and contained 4.8 feet in depth of round grained yellow beach sand, with an area of 113 square feet. Different sizes of sand were introduced by the owners from time to time. The uniformity coefficient varied from 1.3 to 1.7, and the effective size from 0.33 mm. to 0.47 mm. The water from the settling basin passed up through a central well and overflowed over the sand surface. After passing down through the sand the filtered water was collected in 443 screens, which were clamped over openings in the collecting pipes. The holes in the screens were 0.025 inch in diameter. Plate VII, Fig. 2, shows the screen heads on the pipes, together with the surrounding sand over a portion of the bed. These pipes drained to collecting conduits which entered the five-inch effluent pipe leading to the outside. Just outside the filter there was placed a cross connection which allowed water to pass either through the effluent meter and controller to a tank under the floor, or to the sewer, and, also, gave a chance to introduce wash-water in a reverse direction to cleanse the filter.

Controller. The principle of this device was as follows: It was

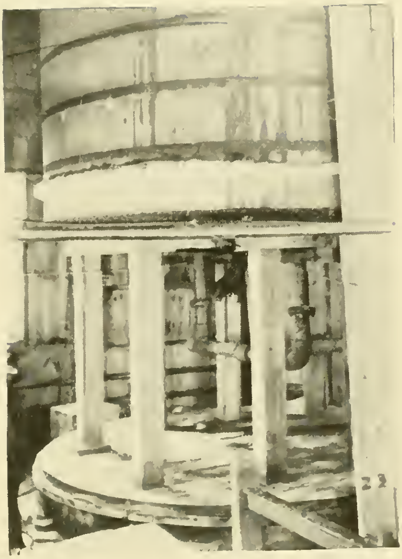

Fig. 1.—Jewell Filter. Interior of Settling Basin.

Fig. 2.—Jewell Filter. Screen Heads on Collecting System.

endeavored to maintain a constant head upon an orifice plate, placed in the bottom, by allowing such water as rose above a certain level to flow over into a cup. This cup was attached to a horizontal arm, the inner end of which operated a butterfly valve in the pipe, which discharged directly over this orifice. A view of this controller is given in Plate VIII, Fig. 1. The efficiency of this device was tested from time to time, and the variations of the flow, as shown by representative tests, are given in Table No. 5, page 167. In this connection, however, reference should be made to a new form of controller recently devised for this use, which has been stated to give satisfactory results.*

Washing. This work was done in the same general manner as with the Warren Filter; the dirty water in this case, however, overflowed in the annular space between the inner and outer tanks and thus away to the sewer. The agitating device, also, was somewhat different. There were two sets of arms and rakes, the larger ones being four feet long and fastened to arms reaching from the center across the filter bed, and placed 180 degrees apart. The shorter arms had only three rakes, were placed at right angles to the others, and stirred the sand close to the central well, which was not disturbed by the rakes on the longer arms. The rakes lay upon the sand of the filter when it was in operation, but when the power was applied in the proper direction, the arms started to revolve and forced the rakes to a vertical position and down into the sand. As the operation of washing was discontinued, the arms were made to revolve in the opposite direction, and the rakes pulled out on top of the bed again in a position nearly horizontal. The device made about seven turns per minute. Plate VIII, Fig. 2, shows the rakes nearly pulled out to the surface of the sand.

At certain times, instead of washing the filter bed, recourse was had to running the rakes around the bed in the direction opposite to that when washing, the water being still upon the surface. This method made furrows about two inches deep in the sand, and was called "trailing." When the bed was new or had recently been thoroughly cleansed by the boiling solution of soda ash, this method was quite effective, for once or twice after a washing, to restore the head lost, and for lengthening thus the time between washings; but at other times its benefit was not so evident.

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*See paper by E. B. Weston, C.E., on "Mechanical Filtration," JOURNAL N. E. WATER WORKS ASSOCIATION, June, 1900, p. 343.

MECHANICAL FILTERS IN GENERAL.

Effect of Washing. An interesting factor in mechanical filtration is the effect which cleansing the filter sand by washing has on the character of the effluent. The results in Table No. 6 have been deduced from observations taken at random under the natural conditions of the work of both filters to show this effect. In general, the

TABLE NO. 6.—BACTERIAL EFFICIENCY OF MECHANICAL FILTERS BEFORE AND AFTER WASHING.

Calendar Date, 1898.		Name of Filter.	Average Bacteria per Cubic Centimeter in Effluent.				
			For Twenty-four Hours.	For One Hour before Washing.		For Twenty Minutes after Washing.	
			Number.	Number.	Per Cent. of Average for Twenty-four Hours.	Number.	Per Cent. of Average for Twenty-four Hours.
March	31	Warren	69	32	46	326	473
April	1	,,	69	54	78	271	393
,,	1	,,	220	294	134	387	176
,,	2	,,	220	126	57	444	202
,,	14	,,	79	73	92	160	203
,,	19	Jewell	96	55	57	338	352
,,	20	Warren	32	14	44	233	729
,,	20	Jewell	96	59	61	329	353
,,	21	Warren	6	4	67	38	633
,,	23	,,	15	8	53	52	347
,,	24	,,	15	51	340	47	313
May	3	Jewell	36	29	81	175	486
,,	6	,,	28	6	21	205	732
June	2	Warren	105	79	75	516	491
,,	2	,,	100	60	60	469	469
,,	6	,,	17	6	35	21	124
August	12	,,	165	11	7	1 180	715
,,	13	,,	165	166	101	549	333
Average,		—	85	63	74	319	375

number of bacteria was about five times as many immediately after washing as before, and quite often a greater turbidity of the effluent was noticeable. It was observed that under normal conditions, that is, with applied water of about the average muddiness, and with the same amount of coagulant used directly after washing as was ordi-

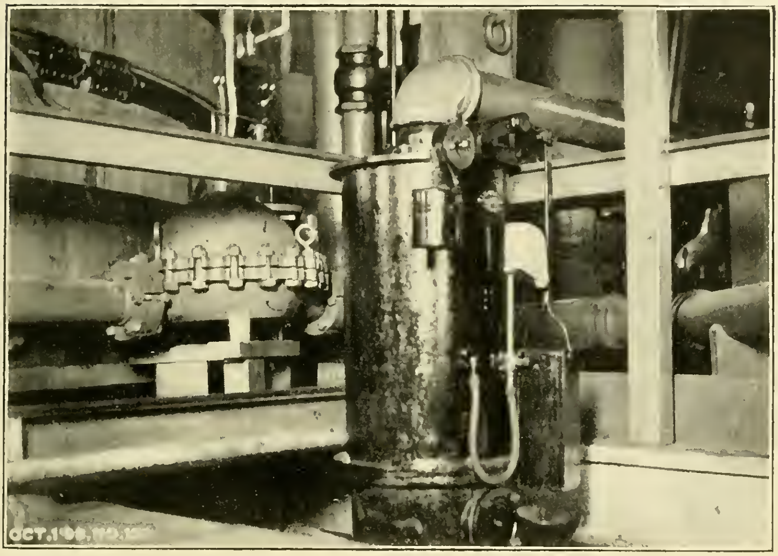

Fig 1.—Jewell Filter. Controller.

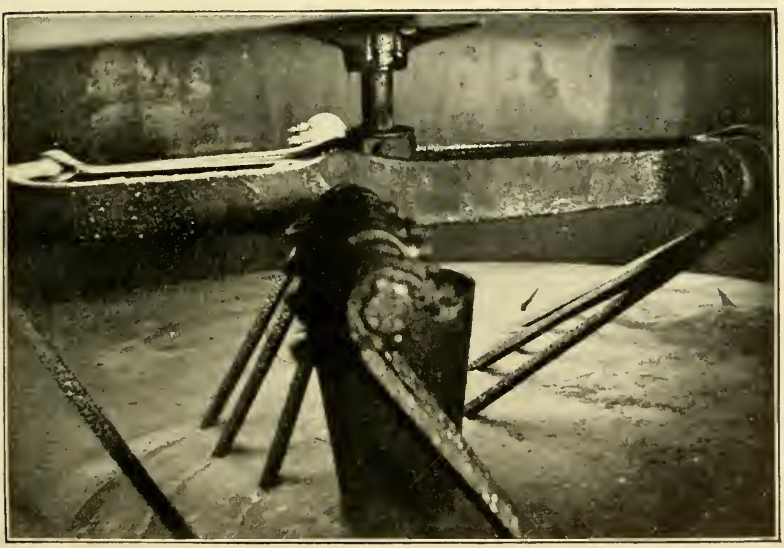

Fig. 2.—Jewell Filter. Agitator.

narily used to secure good results, this poor condition of the effluent extended over a period of about twenty minutes. If large quantities of coagulant were used directly after washing, — that is, considerably more than the average amount necessary for good results with the given condition of the water, — these higher numbers of bacteria would obtain for a short time only, say five or ten minutes, and then to a much less degree.

Effects of Using Different Quantities of Coagulant. During the months of May and June, 1897, special experiments were made to determine the effect of using large quantities of coagulant, and none at all.*

In general, after using a normal amount of coagulant, the effect of not using any was apparent by a somewhat turbid effluent about forty-five minutes after shutting off the supply of coagulant. In two hours the number of bacteria was from one half to about the same number as in the applied water, and the effluent was very much the same in appearance. The time needed for a filter to recover itself, after operation without coagulant, by using a large amount (in this particular case 2.75 grains per gallon) was the same, or about two hours.

Whirling Motion. It has been brought out by Mr. E. B. Weston in his very interesting paper on "Mechanical Filtration," presented

TABLE No. 7.

Effect of Whirling Motion upon Settling with Coagulation.

Month, 1898.	Bacteria per Cubic Centimeter. Applied Water.	Settled Water. Warren.	Settled Water. Jewell.
February	9 430	7 130	7 190
March	11 750	6 160	5 780
April	5 000	3 360	3 620
July	16 800	10 900	10 900
August	15 100	7 550	7 780
Averages	11 600	7 020	7 050
Date, 1898.	Amount of Suspended Matter. (Parts per 100 000.)		
August 15	3.9	3.6	2.8
August 29	2.4	0.6	0.8
Averages	3.1	2.1	1.8
Ratio of capacity of settling basin to daily quantity	——	.0359	.0244

* For details see Report of Filtration Commission, pp. 170, 171.

TABLE NO. 8. — AVERAGE DAILY RESULTS OF MECHANICAL FILTERS, BY MONTHS.

MONTHS, 1898.	Hours in Operation per Day.		Rate of Filtration in Million Gallons per Acre Daily.		Ratio of Washing Time to Operating Time in Percentage.		Per Cent. of Filtrate used in Washing.		Sulphate of Alumina. — Grains per Gallon.		Turbidity.			Bacteria per Cubic Centimeter.			Percentage of Bacteria Removed.	
											Applied	Effluents.		Applied	Effluents.			
	War-ren.	Jew-ell.	War-ren.	Jew-ell.	War-ren.	Jew-ell.	War-ren.	Jew-ell.	War-ren.	Jew-ell.	Water.	War-ren.	Jew-ell.	Water.	War-ren.	Jew-ell.	War-ren.	Jew-ell.
January	10.1	8.1	117	85	2.3	3.4	4.8	8.8	1.19	0.72	{ 0.29 W 0.16 J	.001	—	{ 19 550 W 12 950 J	950	1 980	95.14	84.70
February . . .	21.3	20.7	104	98	1.4	2.1	3.8	6.1	0.70	0.56	0.15	.005	.004	9 430	238	638	97.48	93.23
March	22.3	22.2	108	106	0.9	1.2	3.5	4.3	1.81	1.07	0.30	.001	.001	11 750	164	208	98.60	98.23
April	23.0	22.9	122	106	0.7	0.7	2.6	2.8	0.86	0.54	0.08	.001	.000	5 000	78	159	98.44	96.83
May	23.6	23.2	115	106	0.8	1.2	2.6	4.6	1.55	1.00	0.19	.015	.000	10 800	630	150	94.20	98.61
June	23.3	22.8	103	106	1.0	1.4	3.9	5.4	1.36	1.18	0.19	.001	.008	11 100	115	1 450	98.96	86.90
July	19.5	22.2	119	103	1.4	1.8	5.1	7.6	1.46	1.31	0.11	.003	.008	16 800	320	345	98.10	97.95
August	23.2	22.9	137	103	1.5	1.5	5.1	6.3	1.76	1.35	0.36	.016	.000	15 100	290	260	98.08	98.28
Average, 6 months.	22.1	22.3	115	104	1.1	1.4	4.0	5.3	1.32	0.97	0.20	.004	.002	11 500	201	293	98.25	97.45

NOTE. — During the month of May with the Warren filter and the month of June with the Jewell filter, special experiments with varying quantities of coagulant were made. Averages do not include these months, nor the month of January.

to this Association January 10, 1900,* that, by having a whirling motion of the water at the entrance to the settling basin of the Jewell Filter, there is a considerable gain in the precipitation of suspended and organic matter. So far as the writer knows, there is presented in the preceding table, No. 7, for the first time, actual numerical data upon results with the same water under conditions of whirling and without. The quantities of coagulant added to the two filters are not sufficiently different to seriously affect the results and conclusions, but are, in general, larger for the Warren. It will be seen that the effect of the coagulation in each settling basin is about the same, although the Warren has fifty per cent. greater capacity in proportion to the daily quantity. The water in this settling basin takes a somewhat winding but quiet course, while in the Jewell it is given a rapid whirling motion.

The quantitative and bacterial results obtained with the mechanical filters, tabulated by months, are given in Table No. 8. The

TABLE NO. 9. — AVERAGE RESULTS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM THE ALLEGHENY RIVER, AND SAND AND MECHANICAL FILTERS, DURING THE SEVEN MONTHS ENDING AUGUST 31, 1898.

(PARTS PER 100 000.)

CONSTITUENTS.	River Water.	Effluents.				Percentage of Constituents Removed.			
		Sand Filters.		Mechanical Filters.		Sand Filters.		Mechanical Filters.	
		No. 1.	No. 2.	Warren.	Jewell.	No. 1.	No. 2.	Warren.	Jewell.
Turbidity	—	0.010	0.012	0.000	0.001	—	—	—	—
Color	0.26	0.07	0.07	0.03	0.03	73	73	88	88
Nitrogen as									
Albuminoid Ammonia	0.0101	0.0054	0.0053	0.0047	0.0043	47	48	53	57
Free Ammonia . .	0.0020	0.0018	0.0018	0.0019	0.0018	10	10	5	10
Nitrites	0.0000	0.0000	0.0000	0.0000	0.0000	—	—	—	—
Nitrates	0.0568	0.0642	0.0549	0.0550	0.0520	-13	3	3	8
Chlorine	1.87	1.84	1.77	1.76	1.65	2	5	6	12
Total Solids	15.4	10.8	10.6	9.5	9.4	30	31	38	39
Suspended Matter . .	5.3	0.0	0.0	0.1	0.1	100	100	98	98
Total Hardness . . .	3.21	4.31	4.33	2.96	2.89	-34	-35	8	10
Alkalinity	2.44	3.53	3.56	1.64	1.69	-45	-46	33	31
Sulphuric Acid . . .	1.15	1.15	1.15	1.86	1.59	—	—	-62	-38

*JOURNAL, June, 1900, pp. 349, 358, 359.

averages of the chemical constituents of the applied water and of the effluents of the mechanical filters, also compared with those of the sand filters for the same seven months, are given in Table No. 9.

WORMS TILE FILTER.

The process of water purification by the Wormser System as tried at Pittsburgh was twofold: first, a preliminary treatment by the addition of chloride of iron and removal of some matter by passage through broken stone; and second, a filtration through the tiles.

Tiles. The tiles were made in Germany, and were composed of sand and broken glass baked in a mould. They were about thirty-nine inches square and four inches thick. In the center of each there was an open chamber of about one-half cubic foot capacity, into which the filtered water passed. On Plate IX, Fig. 1, there is a view of a tile ready to be placed in the tank, showing the method of making the pipe connection by gasket to the hole leading to the interior of the tile.

Washing. The tiles were washed by a reverse current of filtered water, with a head of 19.5 feet above the center of the tiles. Care was taken in washing the tile to let on the wash-water pressure slowly and maintain the flow uniformly. Nevertheless, as soon as the tiles became sufficiently clogged to begin to produce a good effluent, they all became broken one after another when being washed. Plate IX, Fig. 2, shows the line of breakage on two of the tiles, and also an idea of the interior construction.

Results. In Table No. 10 are presented the average bacterial results by months, obtained with this system of filtration. It will be seen that the tiles themselves do not appear to have materially reduced the number of bacteria from those in the water flowing from the settling tanks, which had been treated with coagulant.

BOILER EXPERIMENTS.

The use of water for industrial purposes is an important consideration in Pittsburgh, or, indeed, in any large manufacturing city. It was considered advisable to learn what the effect would be of clarifying and filtering the Allegheny River water prior to its use in boilers.

Three new 25 H. P. boilers were kindly loaned by the Oil Well Supply Co., for the purpose of an experiment in this line. A view of these boilers in position is given on Plate X, Fig. 1. Boiler

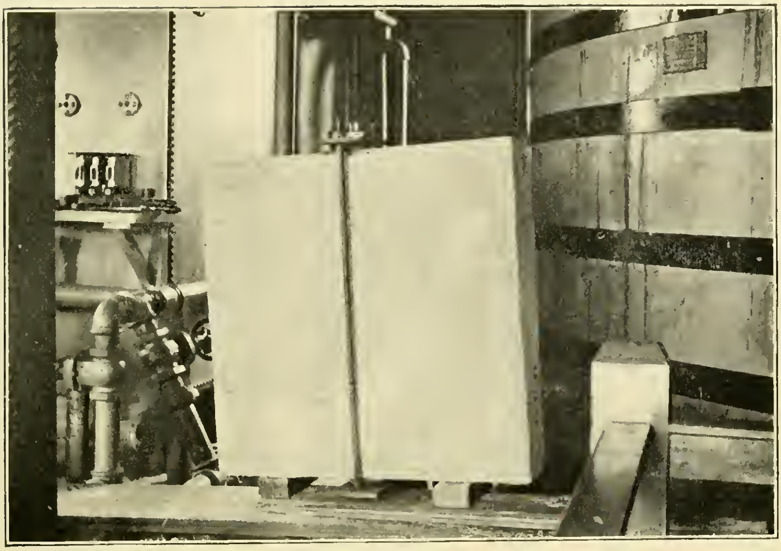

FIG. 1.—WORMS TILE, WITH FITTINGS.

FIG. 2.—WORMS TILES, BROKEN IN SERVICE.

TABLE NO. 10.—AVERAGE BACTERIAL RESULTS WITH WORMS TILE FILTER.

Month, 1897–98.	Bacteria per Cubic Centimeter.									Percentage of Bacteria Removed.							
	Applied Water.	Settled Water.	Effluents.			Settled Water.	Effluents.			Settled Water.	Effluents.			Settled Water.	Effluents.		
		Tank No. 3.	Tile A.	Tile B.	Tile C.	Tank No. 4.	Tile D.	Tile E.	Tile F.	Tank No. 3.	Tile A.	Tile B.	Tile C.	Tank No. 4.	Tile D.	Tile E.	Tile F.
1st Test.																	
December . .	14 430	9 160	8 010	5 280	5 965	12 260	4 990	5 430	4 930	36.60	44.50	63.40	58.70	15.00	65.40	62.30	65.90
January . . .	15 330	7 680	3 050	3 360	2 470	—	6 550	4 120	—	49.90	80.10	78.10	83.90	—	57.30	73.20	—
February . .	9 430	3 290	740	800	1 030	—	—	—	—	65.10	92.20	91.50	89.10	—	—	—	—
March . . .	11 750	4 790	460	630	790	—	—	—	—	59.20	96.00	94.60	93.30	—	—	—	—
2d Test.																	
June	12 000	340	690	470	500	410	510	470	470	97.20	94.30	96.10	95.80	96.60	95.70	96.10	96.10
July	16 800	920	310	400	370	1 010	980	960	590	94.50	98.20	97.60	97.80	94.00	94.20	94.30	96.50
August . . .	16 900	340	100	120	70	360	340	320	110	98.00	99.40	99.30	99.60	97.80	98.00	98.10	99.40
1st Test Average,	12 730	6 230	3 070	2 520	2 560	—	—	—	—	51.10	75.90	80.20	79.90	—	—	—	—
2d Test Average,	15 200	530	360	330	310	600	610	580	390	96.50	97.60	97.80	97.90	96.10	96.00	96.10	97.40

NOTE.—Coagulant was applied to the water in Tank No. 3 all the time; but to the water in Tank No. 4 during June, July, and August only.

No. 1 was supplied with the effluent from the sand filters, No. 2 with the effluent from the mechanical filters, and No. 3 with the unclarified river water. After these boilers had been in service for about two and one-half months, they were blown off hot; samples of scale were collected, and an examination was made of the interior of each. The results of the chemical analyses of the scales are given in the following table, No. 11: —

TABLE No. 11.

Results of Chemical Analyses of Boiler Scales.

Samples Collected September 17, 1898.

Items.	Boiler No. 1.	Boiler No. 2.	Boiler No. 3.
	Parts by Weight.		
Calcium carbonate	53.21	27.42	3.34
Calcium sulphate	13.06	53.88	0.75
Magnesium carbonate	25.33	12.58	11.06
Sodium chloride	5.74	1.64	0.39
Iron and aluminum oxides	1.42	3.64	16.66
Insoluble matter	1.24	0.84	67.80
Totals	100.00	100.00	100.00

Scale. It will be seen that scale from the boilers using the effluent from the sand filters was composed largely of the carbonates of calcium and magnesium, which are not as troublesome as sulphates. It was said that, by cooling down slowly, the formation of this kind of scale could have been in a measure prevented. It will be noticed that the scale from the boiler using the effluent from the mechanical filters was composed largely of sulphate of calcium, which is what would be expected from the chemical action caused by the addition of sulphate of alumina to the water. The scale upon the third boiler was soft and composed largely of mud and insoluble matter; material which could have been largely removed by judicious blowing out from time to time.

The statement of the practical boiler mechanic, who examined the interiors after the experimental use, was that boiler No. 3 was in the best condition. This problem must be considered far from settled, however, on the basis of such a limited experiment.

CHEMICAL ANALYSES.

The following pages contain tables giving a statement of the average chemical analyses by months of the samples of river water and the various effluents.

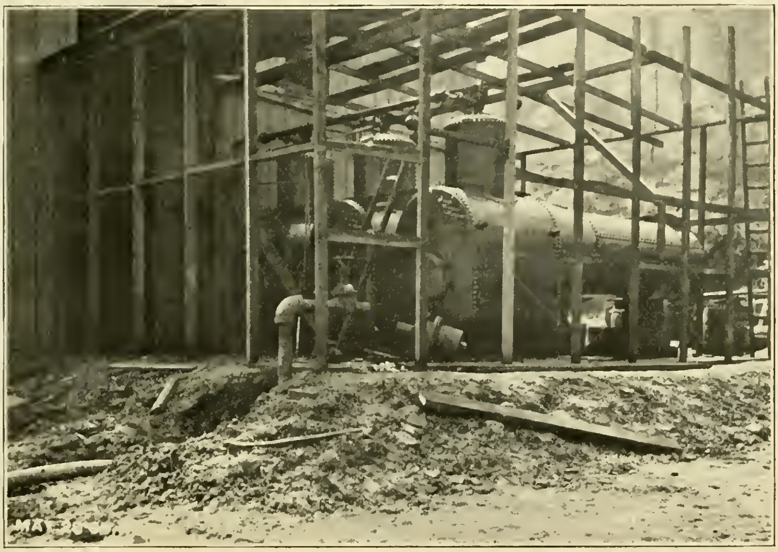

FIG. 1. — EXPERIMENTAL BOILERS.

TABLE NO. 12A.—AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM ALLEGHENY RIVER AT BRILLIANT.

(PARTS PER 100 000.)

Year.	Month.	Color.	Nitrogen as Albuminoid Ammonia.	Nitrogen as Free Ammonia.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
1897 .	June . . .	—	0.0137	0.0006	0.0000	0.0175	2.40	14.1	—	7.65	—	1.40	—
,, .	July . . .	—	0.0307	0.0034	0.0001	0.0106	3.13	26.9	11.1	5.84	6.08	1.33	0.184
,, .	August . .	—	0.0210	0.0023	0.0000	0.1050	2.03	9.0	1.0	5.41	4.05	0.86	0.007
,, .	September .	0.37	0.0133	0.0019	0.0000	0.0650	2.70	13.1	—	5.03	4.63	1.82	0.063
,, .	October . .	0.23	0.0120	0.0017	0.0000	0.0550	3.81	17.7	—	5.49	5.09	2.31	0.046
,, .	November .	0.29	0.0152	0.0019	0.0000	0.0700	3.15	19.7	2.0	3.89	3.51	2.47	0.095
,, .	December .	0.30	0.0111	0.0015	0.0000	0.1075	2.11	23.7	10.7	2.24	1.72	1.79	0.123
1898 .	January . .	0.28	0.0074	0.0016	0.0000	0.0885	1.53	15.3	4.8	2.09	1.48	1.43	0.112
,, .	February . .	0.21	0.0099	0.0020	0.0000	0.1425	1.46	11.9	1.4	2.59	1.73	1.24	0.059
,, .	March . . .	0.24	0.0076	0.0015	0.0000	0.0487	1.29	14.0	4.3	2.72	1.75	1.18	0.040
,, .	April . . .	0.22	0.0077	0.0018	0.0000	0.0458	1.36	9.4	0.2	2.29	1.83	1.08	0.041
,, .	May . . .	0.30	0.0164	0.0015	0.0000	0.0180	1.66	20.7	11.9	2.80	2.13	1.00	0.033
,, .	June . . .	0.25	0.0085	0.0019	0.0000	0.0300	2.42	19.1	9.0	3.51	3.10	1.04	0.010
,, .	July . . .	0.27	0.0100	0.0027	0.0000	0.0694	2.47	13.1	1.4	4.53	3.41	1.55	0.020
,, .	August . .	0.31	0.0103	0.0024	0.0000	0.0435	2.42	19.5	8.8	3.99	3.15	0.93	0.020
Average, 15 months .		0.27	0.0130	0.0019	0.0000	0.0611	2.26	16.5	5.4	4.00	3.12	1.43	0.061
Average, August, 1897, to August, 1898 . .		0.27	0.0116	0.0019	0.0000	0.0684	2.19	15.9	5.0	3.58	2.89	1.44	0.051
Average, January, 1898, to August, 1898 . .		0.26	0.0097	0.0019	0.0000	0.0608	1.83	15.4	5.2	3.06	2.32	1.18	0.042

TABLE NO. 12B. — AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM GATE CHAMBER.

(PARTS PER 100 000.)

YEAR.	MONTH.	COLOR.	NITROGEN AS				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897 .	July . . .	—	0.0260	0.0020	0.0001	0.1481	1.12	15.0	6.0	4.39	4.71	1.07	0.185
,, .	August . .	0.45	0.0222	0.0015	0.0000	0.0763	1.63	14.1	4.3	5.44	5.13	1.10	0.177
,, .	September .	0.32	0.0128	0.0017	0.0000	0.0471	2.47	13.3	—	5.75	4.95	1.86	0.044
,, .	October . .	0.26	0.0141	0.0018	0.0000	0.0670	3.41	17.2	—	5.30	4.92	2.47	0.052
,, .	November .	0.29	0.0148	0.0017	0.0000	0.0557	3.13	21.3	3.6	4.15	3.73	2.48	0.114
,, .	December .	0.30	0.0085	0.0014	0.0000	0.1012	1.73	15.8	3.5	1.84	1.44	1.63	0.125
1898 .	January . .	0.26	0.0070	0.0012	0.0000	0.0915	1.37	14.4	4.6	2.11	1.60	1.37	0.118
,, .	February .	0.24	0.0106	0.0014	0.0000	0.1400	1.29	12.7	2.4	2.80	1.86	1.15	0.116
,, .	March . . .	0.23	0.0102	0.0030	0.0000	0.0495	1.18	22.2	12.0	2.88	1.91	1.66	0.064
,, .	April . . .	0.23	0.0083	0.0021	0.0000	0.0544	1.29	9.0	0.1	2.75	2.11	1.14	0.040
,, .	May . . .	0.29	0.0116	0.0011	0.0000	0.0300	1.39	11.0	2.7	2.79	2.19	0.74	0.042
,, .	June . . .	0.25	0.0089	0.0022	0.0000	0.0394	2.16	17.8	7.7	3.34	3.15	1.13	0.013
,, .	July . . .	0.26	0.0098	0.0028	0.0000	0.0694	2.44	12.7	0.9	4.56	3.47	1.36	0.022
,, .	August . .	0.29	0.0107	0.0025	0.0000	0.0450	2.35	19.7	8.6	4.03	3.16	1.01	0.016
Average, excluding July, 1897 . . .		0.28	0.0115	0.0019	0.0000	0.0667	1.99	15.5	4.6	3.67	3.05	1.47	0.073

TABLE NO. 12C.—AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM SETTLING BASIN.

(PARTS PER 100 000.)

YEAR.	MONTH.	COLOR.	NITROGEN AS				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897 .	July . . .	—	0.0234	0.0031	0.0000	0.1075	1.70	14.0	5.5	4.73	6.05	1.44	0.147
,, .	August . .	0.45	0.0204	0.0015	0.0000	0.0675	1.65	11.4	1.3	5.71	5.12	1.10	0.088
,, .	September .	0.32	0.0131	0.0019	0.0000	0.0408	2.63	13.9	—	5.47	4.91	1.84	0.041
,, .	October . .	0.24	0.0133	0.0017	0.0000	0.0703	3.26	17.0	—	5.13	4.86	2.36	0.048
,, .	November .	0.26	0.0147	0.0021	0.0000	0.0600	3.58	20.4	2.2	4.42	4.02	2.16	0.119
,, .	December .	0.29	0.0089	0.0014	0.0000	0.0806	1.84	11.9	0.4	2.31	1.89	1.26	0.102
1898 .	January . .	0.22	0.0061	0.0014	0.0000	0.1069	1.47	12.0	1.7	2.06	1.67	1.51	0.126
,, .	February .	0.24	0.0101	0.0017	0.0000	0.1500	1.38	11.1	0.3	2.94	1.91	1.14	0.088
,, .	March . . .	0.22	0.0085	0.0014	0.0000	0.0450	1.24	10.4	0.4	2.81	1.87	1.00	0.038
,, .	April . . .	0.20	0.0084	0.0026	0.0000	0.0431	1.45	9.1	0.1	2.69	2.07	1.25	0.045
,, .	May . . .	0.27	0.0088	0.0012	0.0000	0.0255	1.30	9.3	1.2	2.58	2.18	0.79	0.040
,, .	June . . .	0.23	0.0083	0.0020	0.0000	0.0300	2.12	12.2	2.3	3.27	2.96	0.95	0.014
,, .	July . . .	0.24	0.0095	0.0026	0.0000	0.0637	2.67	14.6	2.2	4.61	3.30	1.55	0.021
,, .	August . .	0.29	0.0104	0.0024	0.0000	0.0495	2.45	16.7	5.4	3.97	3.08	1.02	0.015
Average, excluding July, 1897 . . .		0.27	0.0105	0.0018	0.0000	0.0641	2.08	13.1	1.6	3.69	3.07	1.38	0.060

TABLE NO. 12D.—AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM SAND FILTER NO. 1.

(PARTS PER 100 000.)

Year.	Month.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897	July	—	0.0184	0.0051	0.0001	0.1243	2.02	28.9	1.2	6.59	9.12	1.26	0.127
,,	August	0.35	0.0100	0.0009	0.0001	0.0707	1.51	10.3	—	7.30	7.16	1.07	0.034
,,	September	0.06	0.0076	0.0014	0.0000	0.0548	2.43	13.8	—	6.52	6.07	1.91	0.006
,,	October	0.00	0.0078	0.0017	0.0000	0.0816	3.12	17.4	—	5.99	5.60	2.52	0.006
,,	November	0.10	0.0097	0.0014	0.0000	0.0771	3.62	18.5	0.0	5.01	4.74	2.23	0.024
,,	December	0.02	0.0056	0.0015	0.0000	0.0937	1.90	11.7	0.0	3.26	2.81	1.36	0.031
1898	January	0.12	0.0049	0.0011	0.0000	0.1020	1.39	9.9	0.0	3.13	2.63	1.52	0.028
,,	February	0.10	0.0077	0.0013	0.0000	0.1625	1.44	10.9	0.0	3.23	2.68	1.22	0.028
,,	March	0.00	0.0040	0.0016	0.0000	0.0525	1.23	9.5	0.0	3.59	2.74	1.05	0.016
,,	April	0.02	0.0050	0.0021	0.0000	0.0469	1.56	8.7	0.0	3.46	2.88	1.14	0.010
,,	May	0.09	0.0048	0.0010	0.0000	0.0270	1.31	8.3	0.0	4.12	3.30	0.86	0.012
,,	June	0.06	0.0057	0.0016	0.0000	0.0412	2.14	11.2	0.0	4.42	4.10	1.01	0.004
,,	July	0.09	0.0055	0.0023	0.0000	0.0731	2.60	14.2	0.0	5.97	4.67	1.66	0.005
,,	August	0.12	0.0050	0.0022	0.0000	0.0465	2.56	12.5	0.0	5.36	4.37	1.12	0.004
Average, excluding July, 1897		0.09	0.0064	0.0015	0.0000	0.0715	2.06	12.1	0.0	4.72	4.13	1.44	0.016

TABLE NO. 12E.—AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM SAND FILTER NO. 2.

(PARTS PER 100 000.)

Year.	Month.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897 .	July . . .	—	0.0158	0.0059	0.0001	0.1158	1.90	23.9	4.4	7.25	22.15	1.99	0.130
,, .	August . .	0.35	0.0101	0.0009	0.0000	0.0760	1.58	10.5	—	7.35	7.20	1.17	0.036
,, .	September .	0.06	0.0078	0.0015	0.0000	0.0533	2.40	13.8	—	6.63	6.07	2.01	0.004
,, .	October . .	0.00	0.0082	0.0015	0.0000	0.0722	3.17	17.9	—	6.12	5.74	2.55	0.005
,, .	November .	0.09	0.0091	0.0015	0.0000	0.0761	3.35	18.4	0.0	5.68	5.33	2.27	0.023
,, .	December .	0.04	0.0064	0.0012	0.0000	0.0731	1.89	11.5	0.0	3.21	2.76	1.29	0.029
1898 .	January . .	0.11	0.0046	0.0012	0.0000	0.1050	1.42	10.7	0.0	3.47	2.84	1.48	0.025
,, .	February . .	0.08	0.0073	0.0014	0.0000	0.1000	1.41	11.0	0.0	3.50	2.77	1.22	0.041
,, .	March . . .	0.02	0.0039	0.0017	0.0000	0.0550	1.24	9.4	0.0	3.81	3.07	1.04	0.026
,, .	April . . .	0.02	0.0046	0.0021	0.0000	0.0469	1.42	8.6	0.0	3.62	3.02	1.14	0.012
,, .	May . . .	0.10	0.0046	0.0011	0.0000	0.0255	1.25	8.2	0.0	3.81	3.32	0.74	0.011
,, .	June . . .	0.05	0.0060	0.0014	0.0000	0.0319	2.16	11.4	0.0	4.58	4.30	1.04	0.003
,, .	July . . .	0.06	0.0057	0.0024	0.0000	0.0769	2.37	13.5	0.0	5.77	4.39	1.54	0.004
,, .	August . .	0.15	0.0049	0.0025	0.0000	0.0480	2.56	12.1	0.0	5.24	4.04	1.30	0.004
Average, excluding July, 1897 . . .		0.09	0.0064	0.0016	0.0000	0.0646	2.02	12.1	0.0	4.83	4.22	1.45	0.017

TABLE NO. 12F.—AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM MECHANICAL FILTERS.

(PARTS PER 100 000.)

YEAR.	MONTH.	COLOR.	Nitrogen as Albuminoid Ammonia.	Nitrogen as Free Ammonia.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
	WARREN FILTER.												
1898 .	February . .	0.04	0.0055	0.0020	0.0000	0.0875	1.34	7.7	0.0	2.04	1.23	1.53	0.009
,, .	March . . .	0.00	0.0039	0.0015	0.0000	0.0487	1.29	7.8	0.0	1.94	1.15	2.00	0.007
,, .	April . . .	0.01	0.0041	0.0016	0.0000	0.0467	1.19	7.9	0.0	1.86	1.31	1.47	0.005
,, .	May . . .	0.05	0.0052	0.0014	0.0000	0.0285	1.38	8.2	0.0	2.66	1.48	1.44	0.014
,, .	June . . .	0.06	0.0049	0.0015	0.0000	0.0319	2.11	10.2	0.0	4.06	2.10	1.93	0.003
,, .	July . . .	0.00	0.0045	0.0018	0.0000	0.0700	2.32	11.5	0.0	3.83	2.42	2.02	0.002
,, .	August . .	0.05	0.0051	0.0032	0.0000	0.0450	2.34	11.7	0.6	4.02	1.65	2.19	0.002
	Average . .	0.03	0.0047	0.0019	0.0000	0.0512	1.71	9.3	0.1	2.92	1.62	1.80	0.006
	JEWELL FILTER.												
1898 .	February . .	0.08	0.0038	0.0017	0.0000	0.0862	1.31	7.8	0.0	2.27	1.41	1.38	0.010
,, .	March . . .	0.00	0.0035	0.0015	0.0000	0.0534	1.17	7.3	0.0	2.09	1.21	1.59	0.006
,, .	April . . .	0.00	0.0042	0.0018	0.0000	0.0475	1.22	7.8	0.0	1.93	1.44	1.21	0.008
,, .	May . . .	0.01	0.0040	0.0013	0.0000	0.0214	1.36	8.1	0.0	2.62	1.49	1.42	0.004
,, .	June . . .	0.05	0.0050	0.0021	0.0000	0.0319	2.03	10.4	0.0	3.83	1.91	2.11	0.003
,, .	July . . .	0.05	0.0047	0.0017	0.0000	0.0600	2.40	13.6	0.9	4.57	2.48	2.23	0.003
,, .	August . .	0.04	0.0058	0.0027	0.0000	0.0435	2.45	11.6	0.5	3.87	2.10	1.72	0.002
	Average . .	0.03	0.0044	0.0018	0.0000	0.0491	1.71	9.5	0.1	3.03	1.72	1.67	0.005

DISCUSSION.

The President. I would like to call upon Mr. Rudolph Hering, C.E., of New York, to give us a little of his experience and observation in connection with sand filters.

Mr. Rudolph Hering. Mr. Chairman, ladies and gentlemen: This last summer the American Society of Civil Engineers held their annual convention in London, and among the subjects which were set down for discussion was that of the filtration of public water supplies. The reason for introducing this subject was to get the opinion, not only of American engineers, but also of European engineers, on the several methods which are now used to purify water supplied for public use. The meeting was well attended, and we had quite a number of discussions, particularly from European engineers. I mention this to call your attention to the fact that this discussion probably forms in a small compass the fullest exposition of authoritative European views that we have up to this time. The papers will be printed in the next volumes of the Transactions of the Society.

The question was brought up for discussion mainly because there is a difference of opinion as to the relative merits of slow or sand filtration, and what we sometimes call rapid filtration, or, more commonly, the mechanical system of filtration. Sand filtration is a slow process, where only from five to ten feet of water, measured vertically, pass through the sand in a day, while in the mechanical filters from 200 to 300 feet of water pass through in a day; therefore the terms "slow" and "rapid" are very characteristic.

The mechanical filters, as you know, are an American production; they have been developed here. The European engineers do not know much about them yet, and have therefore not introduced them for public supplies. It was interesting to hear their opinions on the subject. There were but very few advocates of the mechanical filters, as we might expect, the majority favoring the slow filters, which are the common filters of Europe.

The first slow filter was introduced, seventy years ago, by one of the London water companies, and, therefore, our experience has been quite long. The works, however, were operated more on an empirical than on a scientific basis. We, that is, the Americans, through the Massachusetts State Board of Health, have developed the system of slow filtration more scientifically, and since then much better re-

sults have been obtained in Europe with their filters by making use of the results of our experiments.

While in Europe this summer I visited a number of these filtration plants, and was very much pleased with their results. We are not yet as fully developed in that direction. We have but a few slow filters, although a large number of mechanical filters; yet we are more and more appreciating the necessity of water filtration. As we have new conditions which were not presented in Europe, it has been necessary for us to make extensive experiments, and you probably all know of the careful investigations which were made in Louisville and in Cincinnati, as well as those in Pittsburgh, of which Mr. Knowles has just given us such an excellent description; and at the present time similar experiments are being made in Philadelphia, and have been inaugurated also at New Orleans. These results will give a splendid exposition of the characteristics of very different waters, and have already made it evident that the results found in Europe could not be indiscriminately applied here. When these experiments have all been completed, the water-works engineer will have a very good foundation for his future work in this country.

The European engineers are favored in one particular way, namely, that they continue, you might say, as permanent officers to conduct their works. In our country, as you know, such positions are not so permanent, and, through our political changes, the officers are apt to be disturbed, which hampers them in their efforts to establish the best possible works. In Europe they are continually planning for the future, and for that reason they are in a much better position to attain those excellent results that they have reached than we are. I think this fact should be more generally recognized, and we as engineers should not get the blame that sometimes rests on the profession, because the conditions of our present system of municipal government are responsible for most of the failures. This, by the way, is a subject worth the serious attention of all who are interested in municipal administration. The terms of office of professional officials should be materially lengthened, taken out of politics, and based on merit alone.

The works in Europe are operated with a much smaller per capita water consumption than here, as you know, and that is another point in their favor. They can do better, because they have less to do. The problem with us sometimes becomes enormous. Take, for instance, the city of Philadelphia. There we had to estimate last year

for an amount of water to be filtered equal to the consumption of London of to-day, and in New York the recent propositions are to double even that quantity. So you see the enormity of the questions with which we have to deal, compared with those dealt with in Europe, and for that reason judgment should be a little easy regarding the results accomplished in America. We should not be blamed for at present going ahead slower than they do in Europe, because also the problems presented to us are greater.

I shall say just a few words regarding the larger cities of Europe, and what they are doing to keep their water pure. Last evening I said that Vienna, Glasgow, and Paris, and perhaps one or two more cities, furnished raw water to their inhabitants. All the other cities furnish either ground water or filtered water. In this country it is almost impossible to furnish a large city with ground water, because the consumption is so great, be it on account of waste or greater use of water. Ground waters are, of course, excellent in quality. Such cities as Munich and Dresden, with three or four hundred thousand people, are supplied with ground water, and they have all that they need. The city of Berlin, which, I think, has now a population of a million and a quarter, has filtered water; London has partly filtered water, partly ground water from the chalk wells.

In Hamburg they used raw water from the river Elbe until a few years ago. You probably remember the cholera epidemic which occurred there in 1892. That was due wholly to the pollution of the drinking water, which was pumped from the river directly into the distribution system, and caused that dreadful epidemic. Immediately adjoining Hamburg is the city of Altona, so close that you do not know when you pass from one city into the other, yet their water supplies are entirely distinct. During the cholera epidemic, as you probably know, the cases were limited to Hamburg, although Altona used the water from the same river, with all the Hamburg sewage in it, but filtered it, and, therefore, supplied it to the inhabitants in a purer condition.

Hamburg thereupon immediately began to hurry the construction of its filtration works, and now that city is getting very pure water. The bacteria are reduced in number about ninety-nine per cent. The German government does not think this percentage method of indicating the removal of bacteria a proper one; and, I think, if we reason about it a little, we must all agree that it is wrong. Their specification is that not more than one hundred bacteria shall remain in

a cubic centimeter of water. We have just seen that in the Pittsburgh experiments there were two hundred or three hundred left, notwithstanding ninety-nine per cent. of the bacteria had been removed, so that some of the Pittsburgh effluent would not be good enough, according to the German government rules, and yet, according to our rules, it is sufficiently good.

Another phenomenon which was very noticeable in Hamburg after the introduction of the filtered water was that the typhoid-fever rate immediately dropped from, I think, 20 or 25 per 1 000 down to 3, 4, or 5 per 1 000, which is a very common result after the introduction of filters. We have seen the same thing at Albany, where the largest filter plant in our country exists. These results, and the knowledge we have that the pollution of a water supply, even by a single person, may cause an epidemic of typhoid fever, as in the case of Plymouth, Pa., certainly must cause us all to desire to filter our domestic water supply. Our city governments will, no doubt, eventually see fit to provide the money for such a purpose, and I think it is our duty as engineers to advise them as to the facts and responsibilities in this matter.

The city of Moscow in Russia was not satisfied with the slow filtration process, because it has sometimes yielded water that is not perfectly clear. It, therefore, sent its engineer over here a few years ago to examine into the merits of the rapid or mechanical filters. If you have fine particles of clay suspended in water, ordinary sand filtration will not clear it. The little particles of clay are much smaller than bacteria, and they go through the filter, even though the bacteria may be retained. By the necessary use of alum and consequent coagulation, in the mechanical filters we can keep these fine particles of clay from getting through; and the engineer of Moscow returned to Europe very much in favor of mechanical filters. However, he is now making a series of experiments in order to find out which of the two systems is really the more satisfactory for his conditions, the first series of such experiments to be made in Europe.

The river waters that carry this very fine clay, such as we have in the Ohio and other rivers, cannot always be clarified by slow filtration. Sometimes a previous coagulation by alum will be necessary also with this system.

In Berlin, St. Petersburg, and Warsaw they have also excellent systems of water filtration.

I thank you, gentlemen, for listening to me so patiently.

UNIFORMITY IN MUNICIPAL REPORTS.

BY M. N. BAKER, ASSOCIATE EDITOR, ENGINEERING NEWS.

[*Presented September 19, 1900.*]

Mr. President and Members of the Association: There has been of late a strong and quite widespread movement, as you know, towards securing greater uniformity in municipal accounts and reports. The later and present movement may perhaps be said to have originated through the action of the American Society of Civil Engineers at its annual meeting a year ago, when it was decided to appoint a committee to urge upon the Census Bureau the collection and incorporation of complete municipal statistics in the census returns. Later on the American Society of Municipal Improvements appointed a similar committee to coöperate with the first.

As the work of these two committees progressed, it was found to be impossible for the Census Bureau to do anything whatever in relation to the compilation of municipal statistics prior to 1902, or, in other words, until it had completed its main investigations, the act under which the present census has been taken containing that limitation. Just what will be done after 1902 is as yet unknown, as the Census Bureau is confining its work entirely to the main enumerations, being engaged now on the population, as you know, and having begun also on some of the other main inquiries relating to manufactures and agriculture.

As the agitation on this general subject progressed, one association after another took up the work, each perhaps from a little different point of view; and altogether there have been ten or a dozen national associations of different characters, but all having to do more or less directly with municipal work, that have appointed, or are proposing to appoint at their next meetings, committees on uniform municipal accounts and reports. The general idea which is animating these societies in the appointment of these committees is to have them empowered to secure coöperation between the different societies.

The need for just such coöperation as this is well illustrated by the fact that each of three different societies that aim to secure greater

uniformity in the matter of water-works reports has separately adopted a different schedule, which is not just the very best possible way to secure uniformity, although it is better to have three different schemes than as many as there are water works in the country.

It is very desirable that the three societies in question should have a uniform system of summarizing their statistics in their annual reports. The New England Water Works Association and the American Water Works Association each adopted, at about the same time, a scheme for uniform reports, but the scheme adopted by the American Association has never been put in use by any water works, so far as I know, while the New England schedule has been adopted by a few works. I am glad to see by the last number of the JOURNAL that the number of works adopting it has increased since the last tabulation of the statistics, so that there are now twenty-eight different works that are using this schedule. That, of course, is a small number compared with those represented in the membership of this Association, and much smaller yet when compared with the total number of water works in the country.

The other organization which has worked along this line is the American Society of Municipal Improvements, which, through its committee on municipal data, adopted another schedule for the annual reports a year ago. The original scheme was submitted to the Association two years ago, but so far as I can learn none of the members of that Association has as yet used the schedule formulated by the committee on municipal data. At the meeting of the American Society of Municipal Improvements, held at Milwaukee about three weeks ago, the committee on municipal data and the committee of which I first spoke, to secure action by the Census Bureau, were consolidated, and the new committee is empowered to act with other societies to this same general end.

It is the feeling of the chairman of the committee on municipal data of the American Society of Municipal Improvements that the schedule adopted and in use by the New England Water Works Association is not sufficiently extensive to meet the wants of the present day. That is a question which is certainly open to discussion; or, at least, it is questionable whether any more elaborate schedule than yours would be used to any great extent. The small number of works that have put it in use is good evidence on that point.

It seems to be desirable, in my opinion, to have a committee ap-

pointed by this Association to coöperate with similar committees from other societies. The Central States Water Works Association appointed such a committee to coöperate with a committee from your Association, or from any other, upon this matter of uniform water-works statistics, at its meeting the first of September.

There is, however, a broader field of work in this direction than along the line of water-works statistics alone. It is hoped by those who are interested in the movement in its broader aspects that all phases of municipal activity will be taken up, and that eventually there will be a joint conference committee which will cover the whole subject of municipal accounting and uniform municipal reports, the idea being that each society should do the detail work on its specialty, and then that all of the societies should adopt and try to further the introduction not only of uniformity in one line, but in the other lines. Some of the societies which are taking up this work are interested in all phases of municipal activity, like the National Municipal League, which is now holding its convention at Milwaukee, which will take up this matter on Friday afternoon, and very likely will appoint a strong committee on the subject. This body of which I have just spoken should not be confused with the American Society of Municipal Improvements, nor with the League of American Municipalities, which are two different organizations. The National Municipal League is the organization which has recently formulated and adopted a "Municipal Program," as it is called, which is in effect a skeleton or outline of a model municipal charter. It is a very strong and able organization, and it is hoped that it will take up this matter of municipal accounting from a broad standpoint, and present it and push it along all possible lines. It is a well-organized society with practically a permanent secretary, and is able to push the work onward.

As soon as the various societies have, each in its own field, formulated a scheme for their annual reports, it is to be hoped that they will go into the subject of uniform accounting, and that, later on, work will be begun in the various state legislatures to compel the municipalities of each state to make reports to a state officer in accordance with some uniform scheme. There is in Wyoming a State Examiner of Accounts, who has control of the accounts of the various municipalities, and who has full authority to require the municipalities to make their reports in accordance with his suggestions. Some of the other states in the Union have commissions

which deal with one subject only, like the Gas and Electric Light Commission in Massachusetts, and some of the states have commissions on street railways, and those commissions are requiring uniform reports. It now remains for the specialists, who are connected with such organizations as yours, to lay out schemes in these different fields; to show what is desired, because the municipal legislators, of course, are more or less ignorant on these subjects.

DISCUSSION.

MR. CHARLES W. SHERMAN.* As most of the members doubtless know, since the September issue of the JOURNAL is now in their hands, the statistics of water works, as far as they can be obtained from the reports of the works which have adopted our scheme, for the years 1897, 1898, and 1899, have been compiled, and are published in the September issue of the JOURNAL. This work was done by our senior editor, Mr. Beals, and I am very sorry indeed that he could not be here to present his views on this subject, as the result of his experience in compiling the three years' statistics for publication. I have had quite an extended conversation with him since his report was prepared for the press, and, as far as I can, I would like to give you the benefit of his experience as he has related it to me.

I am quite sure that he feels that our present schedule is, if anything, too elaborate. He says that no two superintendents follow the scheme as originally laid out in exactly the same way, and that, try as hard as he could, he found it absolutely impossible to tabulate some of the statistics presented, without the use of reference notes at the foot of the page, calling attention to some special manner in which a particular superintendent had departed from the scheme; and he questions very strongly whether it is not desirable to reduce the number of items tabulated, so as to make a simpler and less elaborate schedule rather than one so extensive as we have. It is possible, as I have recently heard suggested, that a more elaborate schedule might be adopted as the standard, which should be considered, perhaps, as an ideal which we would like to see followed if possible; and then another, which might be called a schedule of schedules, perhaps, and which should provide for a very condensed summary, even smaller than our present one, might be prepared for more general and uniform application.

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* Junior Editor, N. E. W. W. Assn.

In any event, it seems to me that the subject is one which needs some attention from us. It is generally admitted that we are pio neers in this line and have done about the only good work which has been done, at least in the water-works line; and even that, we must admit, has been very small when, after a lapse of fourteen or fifteen years since the original report was presented, we find no more than twenty-eight cities and towns coöperating in furnishing this summary of statistics.

It is perhaps noticeable to a person who undertakes to compile these statistics that a number of men who seem to be enthusiastic in all the affairs of the Association, — in fact, one at least of our past presidents, — have not yet incorporated this scheme in their annual reports; and I think there is room for missionary work in calling the attention of superintendents to this subject, and in securing a more general adoption of this standard system of tabulating statistics. I think, also, that Mr. Beals' suggestions as to whether or not the schedules should be simplified should be taken up, and that the question of, perhaps, yielding some of our pet schemes, in order to secure greater uniformity throughout the country, if other societies are to adopt standard systems, so that one system may be standard throughout the United States, should be considered.

PROCEEDINGS OF THE NINETEENTH ANNUAL CONVENTION.

September 19 and 20, 1900.

RUTLAND, VT.,
September 19 and 20, 1900.

The headquarters of the Association during the convention were at "The Bardwell," and the meetings were held in the Rutland City Hall.

The following members and guests were in attendance: —

MEMBERS.

Charles H. Baldwin, Lewis M. Bancroft, Oren B. Bates, James F. Bigelow, Forrest E. Bisbee, George Bowers, Fred Brooks, Byron I. Cook, F. H. Crandall, George K. Crandall, George E. Crowell, August Fels, H. M. Gear, Julius C. Gilbert, Thomas C. Gleason, Albert S. Glover, W. J. Goldthwait, Frank E. Hall, J. D. Hardy, V. C. Hastings, W. C. Hawley, Rudolph Hering, Willard Kent, George A. Kimball, Leonard P. Kinnicutt, Morris Knowles, H. N. McIntosh, Theodore H. McKenzie, Thomas McKenzie, William Murdoch, Washington Paulison, Edward L. Peene, Henry W. Rogers, A. H. Salisbury, Charles W. Sherman, George A. Stacy, John C. Sullivan, Robert J. Thomas, William H. Thomas, D. N. Tower, E. L. Wallace, Charles S. Warde, John C. Whitney, W. P. Whittemore, and George E. Winslow. — 45.

HONORARY MEMBER.

F. W. Shepperd. — 1.

ASSOCIATES.

Garlock Packing Co., by J. W. Medick; Hersey Mfg. Co., by James A. Tilden and Albert S. Glover; Henry F. Jenks, Pawtucket, R. I.; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; H. Mueller Mfg. Co., by F. B. Mueller; National Meter Co., by John C. Kelley and J. G. Lufkin; Neptune Meter Co., by D. B. McCarthy; Rensselaer Mfg. Co., by Fred S. Bates; Builders' Iron Foundry, by F. N. Connet; Ross Valve Co., by William Ross; A. P. Smith Mfg. Co., by W. H. Van Winkle; Sumner & Goodwin, by Frank E. Hall; Thomson Meter Co., by Henry C. Folger and S. D. Higley;

Union Water Meter Co., by A. S. Otis; U. S. Cast Iron Pipe & Foundry Co., by John M. Holmes: Sweet & Doyle, by Edmund C. Doyle. — Associates represented, 16, by 19 representatives.

Guests.

Mrs. D. N. Tower, Miss Mary P. Tower, Cohasset, Mass.; Mrs. William H. Thomas, Miss Helen A. Thomas, Hingham, Mass.; Mrs. E. L. Wallace, Franklin, N. H.: Mr. and Mrs. Michael Walsh, Yonkers, N. Y.; Mrs. William H. Van Winkle, Newark, N. J.; Mrs. Byron I. Cook, Woonsocket, R. I.; Miss Mabel A. Bancroft, Miss Jennie M. Wilson, Reading, Mass.; Mrs. A. H. Salisbury, Lawrence, Mass.; Mrs. Edward L. Peene, Yonkers, N. Y.; Mrs. George K. Crandall, New London, Conn.; Hon. John O. Hall, Mrs. John O. Hall, Mr. and Mrs. C. F. Knowlton, Quincy, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mr. and Mrs. James P. Bacon, Cambridge, Mass.; Mrs. Rudolph Hering, New York City; Miss Mary K. Gleason, Ware, Mass.; Mrs. George A. Kimball, Somerville, Mass.; Miss Helen M. Wales, Allston, Mass.; Miss J. M. Ham, Boston, Mass.; M. N. Baker, Associate Editor *Engineering News*, New York City; George E. Mather, Clinton, Mass.; Frederick Law Olmsted, Jr., Brookline, Mass.; L. M. Hudson, C. F. Holyoke, Thomas Burke, Marlboro, Mass.; A. M. Miller, Lt. Col. Corps of Engineers, U. S. A., Washington, D. C.; F. P. Laimon, C.E., Cambridge, N. Y.; Henry C. Meyer, Jr., *Engineering Record*, New York City; A. C. Grover, C.E., C. H. Murdock, A. L. Pratt, A. H. Pierce, L. H. McIntire, Water Committee, R. C. Royce, Hon. John D. Spellman, Mayor, Dr. J. A. Mead, President Howe Scale Co., J. F. Manning, President Columbian Marble Co., S. A. Howard, Superintendent, and Hon. Fletcher D. Proctor, President Vermont Marble Co., Rutland, Vt. — 46.

Summary of Attendance.

Honorary member	1
Members	45
Representatives of Associates	19
Guests	46
	111
Names counted twice	2
Total attendance	109

Wednesday, September 19.

The Association met at 11.30 A.M., President Cook in the chair.

The President. *Ladies and Gentlemen:* It gives me great pleasure to introduce to you His Honor John D. Spellman, Mayor of Rutland.

Address of Welcome by Mayor Spellman.

Mr. President, Ladies and Gentlemen: In behalf of the people of this city it affords me very great pleasure, as their executive officer, to extend to you, members of the New England Water Works Association and your lady friends and other visitors, the freedom and hospitality of our city during your stay among us. In doing so, permit me to say briefly that I have a keen sense of appreciation of this Association and of its purposes, and of the very many material advantages which the intelligence, the proficiency, and the skill of your membership have given to the business and the industrial life of New England cities, towns, and villages. I also have a keen appreciation of the fact that your members doubtless have a pretty fair knowledge, not only of the topography, but of the geography of New England, which in itself must of necessity have had a strong influence in inducing you to hold your annual meeting this year in the "Marble City."

Rutland we are proud of. As you will have an opportunity to observe before you leave us, and as you doubtless have observed already to a certain extent, our little city is pleasantly located, as we believe, in one of the richest and most fertile valleys of the Green Mountain State. It is surrounded by a beautiful amphitheatre of mountains and hills, which make it, at least in my judgment, one of the most charming spots, on account of its natural beauty, in all New England, if not in our entire country. We shall be pleased, very pleased, during your stay amongst us to show you, so far as we may be able in the limited time you are able to give us, the productions of this community. Among our chief industries, as you know, are the great marble quarries and shops, which have been the means of giving to this place, not only something of a national but also something of an international reputation. I again cordially invite you to the freedom and hospitality of our city. [Applause.]

The President. I assure you, Mr. Mayor, that we appreciate the words of welcome you have given us. The hospitality of your state and city is well known, and I have no doubt that our stay here will be profitable and pleasant. In behalf of the Association I invite you and the members of the city government and the citizens generally to be present at our meetings.

New Members Elected.

The Secretary read the following names of applicants for membership: —

For Resident Member.

Nelson E. Mather, Superintendent Water Works, Clinton, Mass.

W. W. De Berard, Assistant Biologist, Metropolitan Water Board, Boston.

Charles F. Knowlton, Commissioner of Public Works, Quincy.

George D. Curtis, Assistant Engineer, City Engineer's Office, Boston.

Charles-Edward Amory Winslow, Assistant in Biological Department, Massachusetts Institute of Technology.

Harry W. Stevenson, Chief Engineer Water Works Plant, Lowell, Mass.

Winfred D. Hubbard, Superintendent Sewers and Water Works, Concord, Mass.

For Non-Resident Member.

Daniel W. Mead, Civil Engineer, Chicago, Ill.

George A. Hotchkin, Superintendent Water Works, Rochester, N. Y.

On motion of Mr. W. H. Thomas, the Secretary was instructed to cast the ballot of the Association in favor of the applicants, and they were declared elected members of the Association.

The President then delivered his annual address, as follows.

ADDRESS OF PRESIDENT BYRON I. COOK AT THE NINETEENTH ANNUAL CONVENTION, RUTLAND, VT., SEPT. 19, 1900.

We are assembled to hold the nineteenth annual convention of this Association, and for a second time in the state of Vermont. Our journey thus far has been very pleasant, and I hope the further proceedings will be as enjoyable. We have again tested the hospitality of the people of the Green Mountain State, and it is found correct.

I will not take time this morning from the more important program that is to follow for any extended remarks, but will simply review the work of the year just closed.

Our net gain in membership for the year has been 24; average for the past five years, 25. The average attendance at our winter meetings was 90.

Our resident active membership is small. Of the three hundred and seventy-three water works in New England, costing over $100 000, only seventy-eight, or less than twenty-five per cent., are represented in our Association. Every water-works superintendent in New England should be a member. It is a duty that he owes to himself and to the plant he operates. We all know that a superintendent with a small salary cannot afford to attend all our meetings, and this is without a doubt the reason why more of the superintendents in the smaller towns are not members. But if a superintendent cannot afford to become a member, the city, town, or company by which he is employed should assume the expense; it will be money well invested. One of the most important questions in water-works management to-day is how to check the waste, and I can safely say that the knowledge which can be gained from the papers read at our meetings, from the association with other members, and from our Journal, will be more effective in checking the waste in any water-works plant than the best meter manufactured, even if it does register one one-hundredth of an inch flow.

The influence and the success of our Association will depend largely on the publication that we issue, and I fully concur with the opinion expressed by Past-President Forbes in his address last year, that our Journal should be the leading water-works publication in this country. The Editors alone cannot make it so, — they need your individual assistance. To their circular issued during the year in regard to advertisers I call your attention, and hope you will aid the Journal in every way possible. There has been an increased demand for the Journal during the year, and this is largely due to the efforts of our Junior Editor, Mr. Sherman, who has so ably performed his duties. Our Journal should be on file in every water department in this country as a reference book for both construction and maintenance.

I hope the day is not far distant when there will be adopted a universal form for the annual reports of municipal water departments, — an object for which this Association has long striven.

The June issue of our JOURNAL, containing a description of the largest sand filter plant in this country, together with a description of the mechanical or American method of filtration, with the discussions by prominent professional gentlemen, is a very valuable book on the purification of water.

The paper on electrolysis, condemning the present method of transmitting electrical power for the operation of street railways, and recommending the double trolley system as the only sure way to prevent the electrical current from escaping into the ground and causing serious injury to the various piping systems, relates to what is probably one of the most important questions that will have to be solved by water-works officials in the next few years.

Mr. Crosby's paper on "Eliminating the Conflagration Hazard," read at our March meeting and not yet published,* the paper being confined to protection from fire by the sprinkler system, presented arguments that must be squarely met by the water-works people, for more than $150 000 000 of property was destroyed by fire in this country last year, and at the present rate the loss this year will be greater. If by united action of the insurance and water-works officials that loss can be reduced, it is our duty to make that effort. The sprinkler system for fire protection is rapidly being extended, requiring larger street mains. A 4-inch sprinkler connection is a thing of the past, and the laying of nothing larger than a 6-inch main to protect a manufacturing industry from fire is sure to result in large loss if a fire occurs.

I hope the Association will take some action on the suggestion contained in Mr. Coffin's paper entitled "A Few Notes on Cast-Iron Pipe," and adopt a standard specification for cast-iron pipe, to be called the New England Water Works Association Standard Cast-Iron Pipe Specification, and that special investigation be made on the coatings of pipes. From personal observation I find that the cast-iron pipe of to-day is not as well coated as in former years.

The committee appointed to revise our constitution are ready to report. Their report, approved by your Executive Committee, has been mailed to each member, and comes up for your action later in the session. I hope that it will be thoroughly discussed and that every member will express his opinion on its provisions.

The Association has lost by death during the year the following members: —

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*Printed in this issue. — EDS.

N. W. CONANT, Superintendent of Water Works, Gardner, Mass., died November 18, 1899.

NATHANIEL DENNETT, Superintendent of Construction, Somerville, Mass., died February 21, 1900.

HORACE B. WINSHIP, C.E., Norwich, Conn., died November 8, 1899.

NATHAN B. BICKFORD, 61 Minot Street, Neponset, Mass., died June 24, 1899.

ANDREW HOLDEN, Water Commissioner, Fall River, Mass.

JAMES W. MORSE, Superintendent of Water Works, Natick, Mass., died September 23, 1899.

JOHN C. HASKELL, Superintendent of Water Works, Lynn, Mass., died June 12, 1900.

Of those who have passed away, Mr. Haskell was probably best known to the members, he having been prominent in the affairs of this Association, serving as its President in 1896 and 1897. He was an active member in every sense, and his work in the Association will be greatly missed.

To the officers and members I wish to express my thanks for their assistance in the management of the affairs of the Association during the year; and I hope you have not had cause to regret the selection that you made for your presiding officer last year at Syracuse.

TREASURER'S REPORT.

Mr. Lewis M. Bancroft, the Treasurer, then presented his annual report, as follows: —

LEWIS M. BANCROFT, TREASURER,

In account with the New England Water Works Association.

RECEIPTS.

1899.			
September 5.	Balance on hand as per last report		$2 712.40
November 16.	Received from Willard Kent, Sec'y . . .	$91.95	
1900.			
January 1.	Received from Willard Kent, Sec'y . . .	78.00	
13.	,, ,, ,, ,, ,, . . .	193.00	
23.	,, ,, ,, ,, ,, . . .	193.80	

January 30.	Received from Willard Kent, Sec'y . . .	$165.00	
February 6.	" " " " " . . .	192.00	
13.	" " " " " . . .	113.40	
March 6.	" " " " " . . .	119.00	
13.	" " " " " . . .	48.00	
April 3.	" " " " " . . .	151.50	
May 1.	" " " " " . . .	143.65	
7.	" " " " " . . .	146.20	
21.	" " " " " . . .	121.20	1 756.70
			$4 469.10

EXPENDITURES.

1899.		
October 20.	J. C. Whitney, salary and expenses	$243.12
	W. H. Richards, salary and expenses	95.00
	Bacon & Burpee, report of September meeting . .	80.00
	Day Publishing Co., September JOURNAL	318.99
December 12.	D. Gillies' Sons, printing and stationery	144.43
15.	J. M. Ham, salary and express	78.69
	Library Bureau, pamphlet boxes	4.80
	W. T. Almy, badges	31.60
19.	Charles W. Sherman, salary and expenses to December 1	97.66
	Boston Society of Civil Engineers, rent to December 1	200.00
1900.		
January 1.	Willard Kent, salary to December 1, postage, etc.,	70.00
	American Society Civil Engineers, book-binding .	6.00
	D. Gillies' Sons, printing	13.92
	J. S. Roberts, express	1.55
15.	Newton Journal, printing	66.00
	W. N. Hughes, receipt book and bill heads . . .	11.45
	Boston Mailing Co., mailing JOURNAL	4.33
	Samuel Hobbs & Co., stationery	3.62
19.	Francis L. Pratt, music at December and January meetings	40.00
	Thomas P. Taylor, stereopticon, December and January meetings	20.00
	Association of Engineering Societies, cuts . . .	5.56
24.	Suffolk Engraving Co., cuts	85.70
31.	Samuel Usher, printing December JOURNAL . . .	291.65
February 1.	J. M. Ham, salary to January 15, and postage and express	50.42
22.	Francis L. Pratt, music at February meeting . .	20.00
26.	Association of Engineering Societies, printing plates	25.00

March	2.	Samuel Usher, printing	$2.25
		Thomas P. Taylor, stereopticon, February meeting	10.00
		W. N. Hughes, perforating lists of subscribers	2.50
		J. M. Ham, salary to February 15, express, etc.	27.33
	9.	Irons & Russell, buttons	178.50
		Willard Kent, salary to March 1, and expenses	80.05
		Charles W. Sherman, salary to March 1, and expenses	94.00
		Boston Society of Civil Engineers, rent to May 1	100.00
	16.	Library Bureau, case and cards	20.85
	21.	D. Gillies' Sons, printing	62.75
		Francis L. Pratt, music at March meeting	20.00
		Evening Post, electrotypes	17.10
April	5.	John Venner, calcium lights, September, 1899, convention	11.00
		John Wiley & Sons, electrotype	1.55
	10.	D. Gillies' Sons, pamphlet envelopes	30.65
		J. M. Ham, salary to March 15, express and postage	30.05
		A. S. Glover, telephones, September, 1899, convention	7.00
		W. N. Hughes, membership book, etc.	19.75
		Boston Mailing Co., mailing pamphlets	1.50
	23.	Bacon & Burpee, reporting winter meetings	66.25
		Hub Engraving Co., plates	46.12
May	2.	Boston Elevated R. R. Co.	10.80
		W. N. Hughes, numbering book	1.75
	8.	Samuel Usher, printing March JOURNAL	252.85
		D. Gillies' Sons, letter heads and envelopes	37.25
		J. M. Ham, salary and expenses to May 15	57.36
			$3 198.70

BALANCE ON HAND.

Deposit, People's Savings Bank	$1 184.03	
Deposit, First National Bank, Reading	86.37	1 270.40
		$4 469.10

LEWIS M. BANCROFT, *Treasurer.*

BOSTON, MASS., September 13, 1900.

Accounts of Treasurer, as per preceding pages, examined and found correct.

A. W. F. BROWN, *Committee on Finance.*

On motion of Mr. August Fels, the report of the Treasurer was accepted and placed on file.

REPORT OF THE SECRETARY.

Mr. Willard Kent, the Secretary, submitted the following report, which was received and placed on file: —

SUMMARY OF STATISTICS RELATING TO MEMBERSHIP FOR YEAR ENDING JUNE 1, 1900.

ACTIVE MEMBERS.

June 1, 1899.	Total active membership		494	
	Withdrawals during year:			
	Resignations	6		
	Dropped	2		
	Died	6	14	
			480	
	Initiations during year:			
	September	9		
	December	14		
	January	4		
	February	7		
	March	5	39	519

HONORARY MEMBERS.

June 1, 1899.	Honorary members		5	
,, 1, 1900.	,, ,,			5

ASSOCIATE MEMBERS.

June 1, 1899.	Total associate membership		73	
	Withdrawals during year		5	
			68	
	Initiations during year:			
	December	1		
	March	1	2	70
June 1, 1900.	Total membership			594

Since June 1 one of our members has died and four have resigned, but the election of five new members makes our total membership at date of this meeting unchanged from that of June 1, 1900.

WILLARD KENT, *Secretary.*

REPORT OF THE JUNIOR EDITOR.

Mr. Charles W. Sherman, Junior Editor, presented the following report, which was received and placed on file: —

BOSTON, July 1, 1900.

To the President and Members of the New England Water Works Association:

It has not been customary hitherto to have a report for the JOURNAL; but bearing in mind the fact that the expenditures on account of the JOURNAL comprise a large part of the cost of running the Association, and that a considerable number of our members who are unable to attend the meetings know nothing more about the affairs of the Association than what they read in its pages, it has seemed to the present Junior Editor that such a report would be of interest to the membership. He therefore submits the following as the FIRST ANNUAL REPORT OF THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Volume XIV of the JOURNAL, which was closed with the issue for June, 1900, contained 375 pages of text and 8 pages of volume index, etc., a total of 383 pages. Including advertisements and covers, the total number of pages printed was 485. It was illustrated by 42 cuts and 26 folded or half-tone plates, the latter of which are not included in the count of pages, although they might well be.

The detailed statement of the contents of the JOURNAL is given in the following table: —

TABLE NO. 1.

Statement of Material in Vol. XIV, Journal of the New England Water Works Association, 1899–1900.

Number.	Issue.	Number of Pages of: Papers.	Proceedings.	Volume Index.	Total Text.	Advertisements.	Total Pages.	Cuts.	Half-tone and Folded Plates.
1	September ..	87	9	—	96	22	118	2	4
2	December...	77	21	—	98	20	118	10	1
3	March	91	5	—	96	20	116	9	13
4	June........	82	3	8	93	20	113	21	8
					383	82	465	42	26
	Covers and Contents						20		
							485		

The total cost of issuing the JOURNAL was $1 954.15, made up as follows: —

TABLE NO. 2.

Cost of Vol. XIV, Journal of the New England Water Works Association, 1899–1900.

Printing	$1 085.71
Engraving, etc.	184.43
Postage on JOURNAL	27.34
Junior Editor's salary	300.00
Stationery and postage	62.61
Incidental expenses	35.38
Reporting meetings	146.25
Printing reprints of papers	112.43
	$1 954.15

The total cost of illustrating was $219.93, or eleven per cent. of the total cost of the JOURNAL. I believe this percentage could be increased with advantage to the JOURNAL. The cost of the illustrations in the *Journal of the Association of Engineering Societies* foı 1899 was about seventeen per cent. of the total cost of issuing tha journal. Lack of funds has operated to restrain us from illustrating papers so fully as we should have liked to do.

The total receipts which should be credited to the JOURNAL have been $1 606.60, made up as follows: —

TABLE NO. 3.

Receipts credited to Vol. XIV, Journal of the New England Water Works Association, 1899–1900.

Advertising	$1 245.00
Sales of JOURNALS	201.65
Saies of reprints	48.65
Sales of cuts	19.30
Subscriptions	92.00
	$1 606.60

It should be noted that this does not include any part of the receipts from members.

The excess of expenditures over receipts is $347.55, which may be considered as the *net cost* of the JOURNAL.

It is worthy of notice that the amount of advertising is less than it was a number of years ago, when the circulation of the JOURNAL and consequently its value as an advertising medium were considerably less. This is due to two causes: first, the withdrawal of their advertisements by some firms which we think ought to advertise with

us; and second, to the formation of "trusts," giving us one advertisement, or none at all, where formerly we had several. The present circulation is: —

Members (all grades)	594
Subscribers	46
	640

In accordance with the custom of the Association, authors have been furnished with fifty reprints of their papers, free of charge. In cases where more than this number were wanted, they have been supplied at cost. The expense of furnishing these reprints to authors has averaged about $4.25 for each paper.

The following table shows that taking into account the difference in the number of copies printed and number of issues during the year, our JOURNAL compares very favorably with the *Journal of the Association of Engineering Societies.*

TABLE NO. 4.

Comparison between the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION *for 1899–1900 and the Journal of the Association of Engineering Societies for 1899.*

	Journal of the New England Water Works Association.	Journal of the Association of Engineering Societies.
Average edition (copies)	1 100	2 200
Issues during year	4	12
Average membership (all grades)	583	1 475
Number of pages of papers	345	544
Do. per 1 000 members	600	369
Total number of pages	485	957
Do. per 1 000 members	832	649
GROSS COST OF JOURNAL:		
Total	$1 954.15	$3 233.44
Per page	4.03	3.38
Per member	3.35	2.19
Per member per 1 000 pages (all kinds)	6.91	2.29
Per member per 1 000 pages (papers)	9.71	4.03
NET COST OF JOURNAL:		
Total	$347.55	
Per page	0.717	
Per member	0.596	
Per member per 1 000 pages (all kinds)	1.23	
Per member per 1 000 pages (papers)	1.73	

Respectfully submitted,

CHARLES W. SHERMAN,

Junior Editor

THE REVISION OF THE CONSTITUTION.

Mr. George A. Stacy, chairman of the committee appointed to prepare a draft for a revised constitution, then addressed the convention. He said: —

The committee appointed to revise the constitution of the New England Water Works Association, when they took the subject in charge, realized that they had no small task on hand, as the constitution was, with very few changes, the one which had been adopted at the organization of the Association years ago, when its numbers were very small. Our present membership is over half a thousand, and it shows the wisdom of those few, who were really the fathers of this organization, that the constitution which was adopted at that time has done its duty so well, and has answered our purpose for so many years. Yet it was felt that the Association had grown to be so large that we ought to consider whether the old constitution did not need some revising or changing. Upon looking the matter over we have come to the conclusion that most of it will do for us to-day; we cannot see that anything we could devise would, in many particulars, serve us any better.

There are certain articles in the old constitution, however, that in our judgment require radical changes. We have had numerous meetings, and have studied and digested the subject to the best of our ability, and have presented the result of our deliberations in printed form, which has been sent to every member of the Association. While we were delegated with full power to report, without consultation with any other members of the Association, we thought best to present our conclusions to the Executive Committee, which has done so much for the success of this Association in times past; whose wisdom, indeed, has very largely carried this Association to its present position of influence and membership. Whatever recommendations they may make in the way of amendments to the printed form of the constitution as we have presented it to you, we will cheerfully accept.

To my knowledge there is only one change that they recommend, and that is in section five of article two, which as reported by us reads: "Members engaging in the business of furnishing water-works supplies shall cease to be Members of the Association and their names shall be transferred to the list of Associates." The

Executive Committee suggests that that be amended so as to read: "Members *hereafter elected* engaging in the business of furnishing water-works supplies shall cease to be Members of the Association," etc. If a motion is made to amend in that way, the members of the revision committee are willing to accept that amendment. And as this report has been in the hands of the members of the Association, as I understand, for quite a while, you are certainly competent to judge whether this is what you want, or whether you want to change it. We have done the best we could. We know our work is not perfect — if we worked over it all our lives it probably would n't be — but this is the best we could do with our experience and our study; and we now present it to you in this printed form for your adoption, amendment, or rejection, as it meets your pleasure.

Mr. Robert J. Thomas. I move that the report of the committee be accepted, and that the new constitution as proposed in their report, with the amendment providing that members "hereafter elected" are the ones referred to in section five of article two, in other words, amending that section so that it shall read: "members hereafter elected," instead of "members" as it reads now, be adopted.

Mr. T. H. McKenzie. I think I do not fully understand Mr. Stacy with regard to the matter of members who are hereafter elected being dropped as Members when they engage in the sale of water-work appliances. I suppose he intends it to apply also to those who are now active members of the Association, if they engage in the sale of water-works appliances. They would under that be transferred, would n't they?

Mr. Stacy. Perhaps I did not make myself clear in this matter, and the phraseology of that section, perhaps, is not just as it should be; but the intention is to leave the members of the Association at the present time in the same standing that they are to-day, and anybody elected to this Association hereafter, or any Member hereafter who ceases to be an active water-works man, in all its true sense, and goes into the business of furnishing water-works supplies, or the business of furnishing us with goods required for the construction and maintenance of water works, shall not be considered an active member, but shall cease at that time to be a Member and shall be put on the list of Associates. It has no effect on the Members' standing in the past, or the Members' standing at the time that this is adopted. I don't know whether I make myself clear or not.

Mr. Julius C. Gilbert. I would like to say a word. I do not

know as it is becoming in me, being a very modest member of this Association, to disagree with or oppose anything which may come up here; but, really, I cannot say that I agree with all these amendments which are offered. I don't know but this is all right; I think that the committee has been honest and has offered it as the best thing to be done; but still, of course, if some of us differ in our opinions, we beg leave to let it be known in the meeting. Here are only a few of us in attendance to-day, compared with the whole active membership, and of course the vote will be small, only a very small number of the members being present to vote on these amendments.

There are a few questions which I would like to ask, and first, in regard to the dues. I for one would be perfectly willing to pay any reasonable amount as dues, if it were necessary, but I would like to ask why the dues are to be raised? If the Association is out of funds and needs more money, then I say raise the dues; but, if we have money enough to get along as we have been getting along, why should we raise them?

But I will go on and not wait for an answer to that question at the present time. Again, in regard to the election of officers; it seems to me that a constitution which has served this Association for so many years, although its membership has increased from a small to a very large number, is all right for the large number. There is no other way in the world of choosing a set of officers so fair, honest, and democratic as by choosing them in open meeting. I understand from the committee that they make this change so that every member of the Association shall have a chance to vote. We all wish that every member could be present and vote at the annual meeting for the election of officers, but that is impossible. Now, it seems to me that those very people to whom you wish to give a chance to vote, who live at a great distance from the headquarters, will, under this amendment, really have no choice in the election of officers, unless they are perfectly satisfied with the list sent out by the nominating committee. If a man lives two or three hundred miles from the place of holding the meeting, he has no other knowledge than that certain men have been nominated for officers, and if they are satisfactory to him he returns his vote by letter. But supposing they are not satisfactory to him? He can, perhaps, send a vote for some one else by letter, but supposing two or three hundred members wanted to vote for some one else other than the nominees, you might have

two or three hundred candidates. That is the main objection that I have to these amendments.

I don't want any member of the committee, or any member of this Association, to think I am saying this to find fault, or that I am dissatisfied in any way whatever personally. I say this only for the best interests of the Association; and from what I have heard since leaving home, it seems to me that the active members of the Association would be better satisfied to have things stay as they are in this respect than to have them as they would be if these amendments are adopted. I want to say this, in closing, that if a majority wants the amendments, I shall go away just as well satisfied as I otherwise would be, for I have no personal feeling in regard to it in any way.

Mr. Stacy. Mr. President, as chairman of the committee I will try to answer the objections of the member who has just made this very frank statement. One objection, I understand, is to the raising of the dues, — that is, if we have got money enough to run the organization without raising them. Now this committee, if it had been satisfied that we were raising money enough with the present dues to run the organization, would have been decidedly wrong in proposing any larger assessment. But the fact is that the finances are going behind, and that is the reason that we recommend raising the dues. We have n't waited until we were in a hole. We have got a good financial foundation now, which is the bed-rock upon which any association must rest, and the committee wants to keep it sound. Now it seems to me that three dollars a year is a pretty small sum for the benefits derived from the meetings of the Association and from our Journal; and that sum is needed from each member, according to the views of your committee, in order to keep the Association up to its present financial standard.

Now, as far as the election of officers is concerned, that is perhaps rather a tender subject. We have been drifting along in the old ruts for a long while, until it has been whispered around amongst a few that there is a possibility of a ring running the Association. It is true that we have been very fortunate in the selection of our Presidents and other officers — with the exception of one President a few years ago — even under the present system of nominating them by a committee. You did n't know whom they were going to nominate,— and they themselves did n't sometimes a half an hour before they made their report. You are fortunate in having such a membership

that the committee could n't make any serious mistake, even if they had taken the names of their nominees consecutively from the membership list. But perhaps the New England Water Works Association won't always keep its membership up to such a high standard that a committee could safely do that; and, at any rate, it seems a rather crude way to do as we have been doing. I know of two or three cases, to speak plainly, where the committee on nominations had no meeting at all, was n't even present at the convention to report, and half an hour before the time for the report a new committee had to be appointed. I know that to be a fact. Now, no committee can do justice to the Association by going in and nominating a set of officers fifteen or twenty minutes before the time the names are brought before the convention, without giving the matter any more consideration than that.

Now, in studying the question how to remedy that defect, as it appeared to us, we looked to other organizations to a certain extent, as we have in our everyday life to look to the experience of others and adapt that to our own situations; and we considered that the method we have proposed was the fairest and most equitable way in which our officers could be selected. You will notice every member is to be notified, and any ten members — you can 't have three or four hundred different sets of nominations for officers — ten members, I think it is, can make nominations for the various offices and present them within a limited time to the Secretary, and they shall be published in the list and be voted upon.

Now, it seems to me, that gives every man a chance to know who the nominees to be voted for are, it gives any ten members who are interested in the Association a chance to get together and make independent nominations, it prevents confusion, and it gives every one a chance to vote intelligently on the officers whom he wishes to have serve the Association for the coming year. If there can be any improvement suggested on that, your committee will be glad to adopt it, and I am sure the Association will. There are but few of us here today, but every member of the Association knows what this proposed amendment is, if he has taken the pains to read the papers which have been sent to him; so it seems to me it comes before you at this time fairly and squarely, and that every man should know how he wants to vote upon it. The purpose of the committee has been to recommend a plan by which every member of the Association might have something to say upon the vital question of who the officers of

the Association shall be. I don't suppose it is perfect, but it seems to me it is a very long step in advance of the old constitution in the method of electing officers, now that the membership has grown so large.

MR. C. W. SHERMAN. Just a word, to supplement Mr. Stacy's explanation. It seems to me that the report of the Treasurer, submitted a few minutes ago, is all the argument that is needed for the increase in dues. If I remember the figures correctly, the amount of money in the treasury a year ago was $2,700, or thereabouts; the amount on hand to-day is between $1,200 and $1,300. I think those figures speak for themselves.

MR. ROBERT J. THOMAS. I would like to say, as a member of the Executive Committee, that we went over these proposed amendments very carefully and discussed them *pro* and *con;* and although some of the members at first were opposed to certain sections in the different articles, after considerable time spent in the consideration of them the committee voted unanimously to recommend them; and that is one reason why I made the motion here to adopt them.

MR. MORRIS KNOWLES. Referring to section five of article two, the proposed amendment, suggested by the Executive Committee, is, as I understand it, to insert after the word "Members" in the first line the words "hereafter elected." I rise principally for the purpose of seeking information upon that, as to whether my interpretation of it is correct. As I should interpret that it would mean that any one hereafter elected to the Association as a member who goes into the business of supplying water-works materials would drop his active membership and become an Associate; but that any one who is now an active member of the Association who enters the business of furnishing water-works supplies would not be affected by this amendment. If that interpretation of it is correct, it seems to me decidedly unfair, — that is, if any one who hereafter connects himself with the Association will be affected by it, and any one who is now a member will not be. If it is desired not to affect any one who has been an active member, and who is now doing work similar to that of an Associate, it seems to me the simplest way to accomplish that is to let the constitution stand as proposed by the committee; for, unless we pass a vote to that effect, the new constitution will not be retroactive and will not affect the old members.

MR. R. J. THOMAS. I don't think Mr. Stacy has got the idea of this proposed amendment exactly as the Executive Committee in-

tended it. Their intention was that the amendment should apply simply to members hereafter elected, and if any present Member of the Association goes into the supply business he is not to be affected by it, nor is any Member who is now engaged in the supply business; but any person hereafter coming into the Association should understand, before becoming a member, that if he goes into the supply business afterwards he is to be transferred to the list of Associates. But we think the present members should have the same right to go into the supply business as those who went into it some years ago, or went into it last year, even though the members hereafter elected should not have that privilege. And I don't see that there is anything unfair in that to the members to be hereafter elected, because they will understand it perfectly before they are elected. The unfairness, I think, would come if we made any discrimination between the members who are now in the supply business and those members who may go into it next year.

MR. STACY. I am glad that this point has been brought up, for I believe in having a clear understanding now, so that there will be no confusion hereafter. As I understand it now, the amendment recommended by the Executive Committee is intended to provide that this section shall have no effect in any shape or manner upon the present membership, but will only have an effect on persons elected to membership in the future.

* * * * * * * *

THE PRESIDENT. I will state that the amendment proposed is as follows: —

"Members *hereafter elected* engaging in the business of furnishing water-works supplies shall cease to be Members of the Association and their names shall be transferred to the list of Associates."

MR. KNOWLES. I would like to offer an amendment to the amendment proposed by the Executive Committee, that is, to strike out the word "elected" after "hereafter"; so it will read: "Members hereafter engaging in the business," etc. And also, to insert after the word "transferred" the words "by the Secretary." The reason for the first amendment is evident, I suppose, from the remarks which have been previously made. The reason for the second is that it will place a definite duty upon a definite person, and will not leave it in an indefinite state.

MR. SHERMAN. With reference to the second of Mr. Knowles'

suggestions, that the duty of transferring such a name from the list of Members to the list of Associates be delegated definitely to the Secretary, I will say that a later section of the revised constitution as proposed here delegates the business of the Association, not otherwise specifically assigned to some officer, to the Executive Committee; and it seems to me preferable that the duty of transferring such a name to the list of Associates should be left to the Executive Committee rather than to a single officer such as the Secretary, because it is sometimes rather a delicate question to decide whether a man has gone into the water-works supply business, or whether he is still a water-works man. For that reason I think the committee is better than the Secretary.

Mr. R. J. Thomas. I don't see why we should discriminate against the members who are not in the supply business now in favor of those who are in the supply business. We can't get at the members who are in the supply business, because we can't pass an article which is retroactive, and I don't believe that is sufficient reason why others, who have been lifelong active, interested members of this Association, should be dealt with differently. There would be nothing unfair to persons coming in hereafter, because we would be taking nothing away from them. They will understand before they come in just what their rights are. But by this proposed amendment to the amendment you are taking something away from the old members, and I don't believe in it. I think the constitution as reported by the committee and approved by the Executive Committee is all right.

Mr. Stacy. I think the point that we should delegate the Secretary to do this work, rather than the Executive Committee, is a small one. The constitution will require them to do it with their other work.

Mr. Knowles. I agree it is a small point, and I have no objection to accepting Mr. Sherman's suggestion as to the Executive Committee.

The President. The motion before the house is on the amendment to the amendment offered by the Executive Committee to section five of article two: "Members hereafter engaging in the business of furnishing water-works supplies shall cease to be Members of the Association, and their names shall be transferred to the list of Associates."

The amendment to the amendment was defeated.

THE PRESIDENT. The motion is now on the adoption of the revised constitution with the section as amended by the committee: "Members hereafter elected engaging in the business of furnishing water-works supplies shall cease to be members of the Association, and their names shall be transferred to the list of Associates."

Adopted, 14 to 5.

MR. W. H. THOMAS. Do I understand this adopts the revised constitution entirely?

THE PRESIDENT. That was Mr. Thomas' motion. The report of your committee is adopted.

MR. J. C. GILBERT. As the constitution as amended has been adopted, I suppose it really takes the authority away from the old Nominating Committee. I would, therefore, move that the present Nominating Committee be reappointed by the President as the committee on nominations.

The motion was adopted, and the President reappointed as the Nominating Committee: J. C. Whitney, Newton, Mass.; C. K. Walker, Manchester, N. H.; F. F. Forbes, Brookline, Mass.; P. Kieran, Fall River, Mass.; D. N. Tower, Cohasset, Mass.

The Secretary read a communication from the Indianapolis Board of Trade, inviting the Association to hold its next convention in that city.

MR. SHERMAN. This new constitution has been so thoroughly read by the members, as has been evinced by the interest taken in it, it is perhaps unnecessary for me to call attention to article eight, section one, which reads: "A convention of the Association for the reading and discussion of papers and for social intercourse shall be held annually at such time and place as may be determined by the Executive Committee." Of course that does not mean that the Executive Committee is not glad to know and would not be governed by the wishes of the members, but the power to determine upon the place for the annual convention is in the hands of the Executive Committee.

MR. STACY. I move that the invitation be referred to the Executive Committee, and that they report upon it at a subsequent meeting.

Adopted.

MR. W. C. HAWLEY. I did n't expect to bring the matter up at this time, but it seems to be in order now, and therefore I will mention it. We would be very glad indeed to have the next convention

of this Association held at Atlantic City. We are unable to offer you very much in the way of entertainment, because Atlantic City has so many conventions, and so many that are large, that bring thousands of people there, that it would be very difficult to secure entertainment for a convention of two or three hundred people. However, we feel sure that the members of the Association would enjoy themselves there, and that we could provide every facility for having a pleasant and profitable time. We would be very glad indeed to see you, and we will do what we can to entertain you.

The President. In behalf of the Association I thank you, Mr. Hawley, for your kind invitation. If there is no objection, Mr. Hawley's invitation will take the same course as that from Indianapolis.

AFTERNOON SESSION.

Mr. Henry F. Jenks made the following report of the Committee on Exhibits of Associate Members.

The following have made exhibits at this convention : —

Meters. — The Hersey Manufacturing Co., South Boston, Mass.; Henry R. Worthington, New York City; Thomson Meter Co., Brooklyn, N. Y.; Union Water Meter Co., Worcester, Mass.; National Meter Co., New York.

Water-Works Tools and Supplies. — Sumner & Goodwin Co., Boston, Mass.; The A. P. Smith Mfg. Co., Newark, N. J.; The H. Mueller Manufacturing Co., Decatur, Ill.

Valves. — Sweet & Doyle, Cohoes, N. Y.; Ross Valve Co., Troy, N. Y.

Miscellaneous. — Henry F. Jenks, Pawtucket, R. I., Drinking Fountains; Garlock Packing Co., Palmyra, N. Y.; Lead-Lined Iron Pipe Co., Wakefield, Mass.

Mr. Peene. Mr. President, as the new constitution allows your conventions to be held outside of New England, the city of Yonkers invites the Association to meet in that city in 1901 or 1902. It is a place central to all railroad lines; it is situated on the banks of the noble Hudson; it is within twenty minutes' ride of the site of the immense distributing reservoir which is now building by the city of New York, and on the north is the immense dam constructed in the valley of the Croton.

The President. I thank you, Mr. Peene, in behalf of the Association, for your invitation. It is very flattering to us that so many cities want us to come to them. If there is no objection, the invita-

tion from Yonkers will take the same course as the other two did this morning.

Prof. Leonard P. Kinnicutt, of the Worcester Polytechnic Institute, Worcester, Mass., then read a paper on "The Purification of Sewage by Bacterial Methods," which was illustrated by charts, diagrams, and tables. It was discussed by Mr. Rudolph Hering, of New York, and the author.

EVENING SESSION.

Mr. Morris Knowles, Assistant Engineer in charge of the testing station, improvement and filtration of water supply, Philadelphia, Pa., described, with the aid of the stereopticon, the filtration experiments and plant at Pittsburgh, Pa.

At the conclusion of Mr. Knowles' address the President called upon Mr. M. N. Baker, Associate Editor of the *Engineering News*, to give a talk on the subject of uniform statistics in municipal reports, reminding the members at the same time that the New England Water Works Association may be said to be a pioneer in that line.*

Mr. Charles W. Sherman. Mr. President, I move you that a committee of three members be appointed to consider this question of uniform statistics, and to consider what, if any, coöperation with other societies is desirable; that the committee be authorized to hold conferences with similar committees from other societies, and to report at a later meeting, whenever the information in their hands is sufficient, as to what steps it seems desirable for this Association to take.

The motion was adopted and the President said that he would announce the committee later.

THURSDAY, SEPTEMBER 20.

The day was devoted to excursions to the marble quarries and other points of interest.

EVENING SESSION.

Mr. J. C. Whitney offered the following resolution: —

Voted, That the thanks of the New England Water Works Association be extended to His Honor the Mayor, to the City Government, and to the

* Mr. Baker's address is printed on page 189 of this issue.

citizens of Rutland; also to the officials of the marble companies and to the Howe Scale Co., for the many courtesies which have made our visit to the Marble City most enjoyable.

Adopted by a rising vote.

The President. We have had with us as a guest during our trip and during our convention a gentleman who is greatly interested in municipal affairs, and it gives me much pleasure to present him to you now, — Mayor Hall, of Quincy, Mass. [Applause.]

Address of Mayor John O. Hall, of Quincy.

Mr. President: I did not anticipate anything of this sort until a little remark which you dropped in my hearing this evening. I expected as your guest merely to join you in the pleasures which you had mapped out for yourselves, to be simply a recipient of your kindness, rather than to take any part in your meetings. It would be the height of discourtesy in me, however, if I did not return to you, Mr. President and gentlemen, my thanks for the invitation to join you in these festivities, and I assure you that the thanks which I return to you are heartfelt and sincere.

Meetings of this sort are of inestimable value. Their influence and their power are beyond calculation. It is a serious mistake if those who are connected with the administration of municipal affairs do not at every opportunity come together for conference, for the interchange of opinions, for the accumulation of facts and experiences outside of their own particular circles, in order that the work which they are called upon to perform may approach to perfection in the highest possible degree. We all have our duties, we all have our burdens, we all have perplexing questions to deal with, which apply to our own individual surroundings, but they are lightened wonderfully by such intercourse as it has been our privilege to enjoy during the past week. We sit with our elbows on the table and our head in our hands, studying to overcome the difficulties that press upon us and which seem to be insurmountable; but after an experience of this sort they vanish into thin air, and an inspiration comes which settles them all, and the problems with which we have struggled and labored for days are solved by our contact with other minds that have also been wrestling with them. You know that if you take two iron pipes that are covered with rust, all corroded, and let them roll together for a little while, the surfaces are smoothed,

and they look more like serviceable pipe. You know that in the process of mechanics the highest degree of polish is secured when certain articles are placed in a tank and rolled and rolled back and forth, and you have all seen them come out shining, glistening, and brilliant. It is just the same with us in our social life, it is just the same with us in our business life, it is just the same with us as we mingle day by day with our fellow men in the accomplishment of those objects which seem to be desirable and essential. And as we mingle together, as we rub one against the other, as mind meets mind, as kindly greeting answers kindly greeting, we go forth brightened and better equipped for usefulness in the spheres which we occupy. That is the result of just such meetings as these; and I return to you my thanks again for just this inspiration and this increased power and this possibility of greater usefulness which I feel have come to me from meeting with you, and which always come from such meetings when we attend them in the right spirit.

Of course I am not a water engineer. Your department is unfamiliar to me in its detail, your minds travel in a channel of which I am almost entirely ignorant; but we are all bound together really in securing the accomplishment of one great end, and that is the improvement of our municipalities, the improvement of our fellow men, and the sending abroad through all the channels which reach into our various communities those things which are useful, beneficial, and necessary for the well-being of the community. There are various obstacles which we meet in each department. I am so fortunate or unfortunate as to be placed at the head of a municipality, in which head all these various branches center, and from which must come the guiding influence which shall lead either to success or to failure and defeat. There are things which must be considered in connection with all these various departments, and it is the business of the chief executive to stand in such relation to the departments that the heads of those departments may be encouraged and assisted in their work for the full accomplishment of the best results. This burden presses itself upon the conscientious chief executive in any community continuously as he considers the various projects for municipal improvement and welfare; and I assure you that it is my personal sympathy with municipal departments which prompts me to assent to your President's request to speak to you to-night.

There is one thing which I think possibly may be of interest to you, and that is the effort which is being made, through the auditors

and through the mayors of the various cities, to secure a uniformity in the administration of municipal affairs. It has been my privilege to be the auditor of the city of Quincy from the time we assumed a city form of government, some eleven years ago. As the auditor, of course, I was a member of the Auditors' Club of Massachusetts. We have had the same difficulty in that organization which is experienced in any organization which only a comparatively small number of its members attend, but nevertheless the influence of our Auditors' Club has been felt all through the community. We exchange our various forms of accounts, we send to one another each month our statement of the standing of the finances of the various cities, we have one or two meetings a year at which we discuss the various problems which arise in connection with the keeping of the accounts; and, although the organization has been in existence only six years, its influence is strongly felt, and it has already resulted in an improved method of keeping accounts.

We early encountered this difficulty, that the difference in the charters of the various cities precluded uniformity in methods and made comparisons very difficult. Through some agitation on our part, and through the same spirit being awakened in the Mayors' Club of the State, there is an effort now being made to secure a uniformity of city charters, in order that all the requirements of the statutes may be complied with in a definite form, and in that way a uniformity in the treating of accounts will also be secured. And if the Auditors' Club and the Mayors' Club can have the assistance in this work of the water departments and of the highway departments, we shall be very glad.

One and all, we are working to improve the communities in which we live and to advance the best interests of the community at large, and of the individual members of it, by intelligent and conscientious effort. This is what we are all laboring for, and we can only accomplish the best results by united action.

Mr. President, I will not detain you longer. I thank you and the members of the Association heartily for the pleasure and profit of this past week.

The President then called upon Mr. Rudolph Hering, of New York, to speak upon the subject of sand filters.*

* Mr. Hering's remarks are printed as a discussion of Mr. Knowles' paper on the "Pittsburgh Filtration Experiments."

Mr. Frederick Law Olmsted, Jr., gave a talk upon "Landscape Problems in the Improvement of the Spot Pond Reservoir, Metropolitan Water Works," illustrated by the stereopticon.

Adjourned.

PROCEEDINGS.

November Meeting.

Young's Hotel,
Boston, November 14, 1900.

President Cook in the chair.

The following members and guests were present: —

Members.

Charles H. Baldwin, Lewis M. Bancroft, Joseph E. Beals, James F. Bigelow, Dexter Brackett, E. C. Brooks, Fred. Brooks, G. A. P. Bucknam, George F. Chace, E. J. Chadbourne, G. L. Chapin, L. Z. Carpenter, John C. Chase, Freeman C. Coffin, R. C. P. Coggeshall, Byron I. Cook, J. W. Crawford, August Fels, Harry F. Gibbs, J. F. Gleason, Albert S. Glover, F. W. Gow, E. H. Gowing, George W. Harrington, William E. Hawks, Horace G. Holden, Willard Kent, Patrick Kieran, A. E. Martin, Frank E. Merrill, Thomas Naylor, C. E. Riley, A. H. Salisbury, Charles W. Sherman, W. H. Sears, J. A. St. Louis, Henry Souther, Robert J. Thomas, William H. Thomas, George W. Travis, D. N. Tower, W. H. Vaughn, William W. Wade, Charles K. Walker, Elbert Wheeler, George E. Winslow.

Associates.

Ashton Valve Co., by C. W. Houghton; International Steam Pump Co., by George J. Foran; Ingersoll-Sergeant Drill Co., by Mellen S. Harlow; Hersey Mfg. Co., by James A. Tilden and Albert S. Glover; Lead Lined Iron Pipe Co., by Thomas H. Dwyer; Neptune Meter Co., by H. L. Kinsey; Perrin, Seamans & Co., by Harold L. Bond; Rensselaer Mfg. Co., by Fred S. Bates; Builders' Iron Foundry, by H. J. Burrough and F. N. Connet; A. P. Smith Mfg. Co., by W. H. Van Winkle; Sumner & Goodwin Co., by Frank E. Hall; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by J. K. P. Otis; United States Cast Iron Pipe & Foundry Co., by John M. Holmes.

Guests.

John F. Farrar, Lincoln, Mass.; H. Walter Gay, Quincy, Mass.; A. F. Hall, Marlboro, Mass.; Caleb Lothrop, Registrar, Cohasset, Mass.; George H. Snell, Superintendent, Attleboro, Mass.; F. L. Weaver and M. J. Dowd, Water Commissioners, Lowell, Mass.

The Secretary read the following names of applicants for membership: —

For Resident Member.

John F. J. Mulhall, Boston, Treasurer of the Portland, Conn., Water Co., and Secretary and Director of various water companies; Lyman P. Hapgood, Superintendent Athol Water Co., Athol, Mass.

For Non-Resident Member.

John Andrew Amyot, M.D., Toronto, Canada, Bacteriologist and Analyst to the Provincial Board of Health of Ontario, Canada; A. M. Miller, Lieutenant-Colonel Corps of Engineers, U. S. A., in charge of the Washington Aqueduct, and of the work of increasing the water supply and constructing the filtration plant of Washington, D. C.; J. J. Smith, C.E., Grand Forks, N. Dak.

On motion of Mr. Coggeshall, the Secretary was instructed to cast the ballot of the Association in favor of the applicants named above, and they were declared elected to membership.

President Cook then read a paper on "Electrolysis," prepared by F. A. W. Davis, Vice-President and Treasurer of the water company, Indianapolis, Ind., who was unable to be present.

Mr. W. J. Sando, formerly Superintendent of Pumping Stations, Metropolitan Water Board, Boston, submitted a "Report of Contract Trial of Thirty Million Gallon Pumping Engine at the Chestnut Hill High Service Pumping Station of the Metropolitan Water Works," which was read by Mr. Charles W. Sherman.

The subject for topical discussion was "Service Boxes," and the discussion was participated in by President Byron I. Cook, of Woonsocket, R. I.; Superintendent A. E. Martin, of South Framingham; Superintendent Charles K. Walker, of Manchester, N. H.; Superintendent Frank E. Merrill, of Somerville; Superintendent R. C. P. Coggeshall, of New Bedford; Mr. F. N. Connet, of the Builders' Iron Foundry; Superintendent Horace G. Holden, of Nashua; Mr. C. W. Sherman; Superintendent Lewis M. Bancroft, of Reading; Superintendent D. N. Tower, of Cohasset; Mr. George E. Winslow, of Waltham; Superintendent Robert J. Thomas, of Lowell; Superintendent Geo. W. Travis, of Natick; Superintendent Frederick W. Gow, of Medford; and Mr. J. F. Gleason, of Quincy.

STANDARD SPECIFICATIONS FOR WATER PIPE.

Mr. E. H. Gowing. I read with some interest Mr. Coffin's paper before the Association last spring in which he referred to standard specifications for water pipe. I think Mr. Coffin wrote a very good paper, but I believe he stopped a little short of the point to which he should have gone. I suppose it was his modesty which made him do so. But I am not so modest as he is, and I think we ought to take some action on this subject, and I would like to ask whether the better way would be to have it brought up for topical discussion some time later in the season, or for me to make a motion now to have a committee appointed to take up the matter on the lines indicated by Mr. Coffin's paper.

The President. I would say, Mr. Gowing, that in my address at Rutland, I alluded to this matter as something which should be taken up by the Association. Possibly it would be a good idea to have a committee appointed to confer with Mr. Coffin, and have the subject brought up for discussion at some subsequent meeting, with a view to issuing standard specifications, to be called the New England Water Works Specifications for Cast-Iron Pipe, so they can be referred to in calling for bids.

Mr. Gowing. Mr. Coffin said a good many things in favor of it, and I am strongly in favor of that idea. I will make a motion that the President appoint a committee to take up this matter, perhaps to call for a discussion during the winter, and then later to make us a report; or, perhaps it would be better, and I will make this motion instead, that the President appoint a committee to consider the subject along the lines of Mr. Coffin's paper, and then let the committee be at liberty to do as they see fit.

Adopted.

The President said he would appoint the committee at the next meeting, and that the subject would be considered at either the February or March meeting.

Adjourned.

OBITUARY NOTES.

Henry Chandler, Clerk of the Water Board of Manchester, N. H., as well as its most prominent member, died October 19, 1900. He was also a Director in the Manchester Manufacturing Company, and Cashier of the Amoskeag National Bank. He had shown great interest in all matters connected with water works.

Mr. Chandler was elected a member of the New England Water Works Association on September 13, 1895.

Ex-Mayor George S. Jenkins, of Lawrence, Mass., who was a member of the Lawrence Water Board for the five years 1894–1898 inclusive, died November 12, 1900. He was elected a member of this Association on February 12, 1896.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XV. March, 1901. No. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

ELECTRICAL CURRENT.

BY F. A. W. DAVIS, VICE-PRESIDENT, INDIANAPOLIS WATER COMPANY.

[*Presented November 14, 1900.*]

Lowell says, "There is no work of genius that has not been the delight of mankind." Some would like to add that this depends upon circumstances. For instance, the electric street railway is not wholly a delight to the water-works manager.

I think it long past the hour when any honest, conscientious man, having knowledge of electricity, will deny the destructiveness of escaping electrical currents from city railways to gas and water pipes and other underground interests. Even the managers of street railway companies are now admitting the fact, and in some cases are asking the gas and water companies to help them take care of the current. Such a request is adding insult to injury.

When Benjamin Franklin sent his kite up in the clouds and brought to the earth enough of the current to identify the lightning of the heavens with the electric fluid, he made a great scientific discovery — the greatness of which he never realized. Neither as yet have we seen the full development of it. Generations to come will see a greater development than we have, and will have a better understanding of electrical energy and the nature of it.

To-day we do not understand the nature of electrical energy, but we know some of the laws that govern it, just as we do of heat and light, to which it seems akin in some respects.

While we point to the destructiveness of this current, we must acknowledge its beneficence and the wonders accomplished by it. We are indebted to the current for the smallest light and also for

the great search-light. Its great power is in evidence every day in driving cars and machinery. Its beneficence is manifested in aiding the surgeon in the examination of the human body and the saving of life. To it we owe our facilities for hearing the distant speaker, the music of the glee club and the band, the reproduction of the voice of a man, though he be dead. When a man is condemned to death in the cause of humanity, to use the language of Milton, —

> "Comes the blind fury with the abhorred shears
> And slits the thin-spun life."

The transmission of the human voice so as to be recognized hundreds of miles away, by the means of the telephone, is so common that we cease to wonder at it. Yet it cannot be contemplated without amazement. Franklin may have had some prophetic vision of the greatness of his scientific discovery, but we doubt it. The full knowledge of this all-pervading, tremendous yet subtle energy that makes its way through heaven and earth is yet to come.

While we extol the usefulness and the marvelous work accomplished by the electrical energy, we rightfully complain of the destruction caused by it, which is permitted by those who are using it, and which is absolutely unnecessary. There are, unquestionably, devices and methods of construction that will do away with the destructiveness of the current, and we should insist that those who create the current shall apply the remedy.

It is claimed that the destruction of water and gas pipes by electrolysis is caused by the current leaving the pipe for another conductor. There is no disputing this fact; but we are not certain that there is not some destruction when the current enters the pipe, for the texture of the iron must in some degree be disturbed. For instance, I have found in the case of screw-joint wrought-iron pipe, in which there is an interruption of the current at every coupling, that the iron was pitted not only where the current left the pipe for the coupling and the coupling for the pipe again, but also where it entered the coupling from the pipe and the pipe from the coupling. We do know that when the electric current for lighting passes from the upper carbon to the lower carbon, both are destroyed, the upper carbon much faster than the lower. The burning of the flesh upon the arm, as the current passes along it, shows destruction from the beginning to the end. At times the current passes through the human body,

destroying life and leaving no visible mark of its departure from the body.

Evidence has been found during the past year that there is destruction of our valves on the inside. Plate II, Fig. 2, shows the destruction of a four-inch valve. In addition to this valve we found one hydrant valve so softened that it could be cut with a knife.

Appeals to the street railway companies for relief have been made, with no favorable response, and now in many States the courts have been called upon for relief and protection for the future. A bill has been introduced into Congress protecting the water mains of the city of Washington. During the coming winter there will be bills introduced in the legislatures of several States for the protection of mains in those States. Cities have granted franchises to street railway companies without protective features in them, although with full knowledge of the damage that is being done to underground interests by these stray currents. They have done the same thing where the cities are the owners of the water works. Patent coatings have been exploited as safeguards against electrolysis. If the patent coating will keep the current off the gas and water pipes, why not paint the rails and keep it in them? It would be much less expense, and would fall upon those who should bear it. Experiments have demonstrated that the so-called coatings afford no protection.

Those who doubt the destruction of gas and water mains by the electrical current should otherwise account for the condition of the mains which has arisen since the introduction of electricity as a propelling power ; also account for the destruction of wrought- and cast-iron mains in less than twelve months ; of lead pipe and wrought-iron services in a few months' time. Expert testimony, while valuable, can have no force as against that of the laborer, who comes in contact with the pipes and sees the actual conditions, — sees the sparks as they pass from one end of the pipe to the other when he separates the ends for repairs ; sees the gas set on fire, endangering his life ; receives a violent shock when he places his tongs on the pipe, and finds that he is obliged to call upon the street car company to come and relieve the pipe of the current ; sees the solder melted on his connections, and the services and mains in the street destroyed ; and knows that gas and water produce none of these conditions. It is a waste of time to tell him that he is mistaken, and that there are technical conditions that make it impossible for the electric current to cause this destruction ; that it is the result of some condition of the soil,

and that the current on the pipe is of no significance. And so it will be with the courts.

Evidence is abundant that bonding pipe and rail is a failure. Superintendents who are relying upon it for protection will realize in the course of time that they have made a mistake in permitting it. As a conductor, water pipes are as faulty as the railway track is with its bad joints. We are never sure that the metal of the bell and spigot are in touch; in fact, we have reason to believe that they seldom touch. We know that when we use a sleeve, the ends of a pipe do not come in contact, and that the yarn holds the pipe from touching the sleeve. The current leaving the pipe in places and shunting at the joints is evidence that the water mains are not good conductors. Knowing these facts, is it not an absurdity to allow the railway companies to bond rail and pipe? Experience with cast welded joints in the track has proven that they are of no benefit in taking the current back to the dynamo. I have been informed that the water mains in Milwaukee show fifty per cent. more current since the rail joints were welded than before. I am of the opinion that there is an ebb and flow in the current. Whenever the rail or pipe has a greater current than it can carry, for the moment the current flows to the earth, and when the pipe or rail is relieved, the current leaves the earth and seeks the pipe and rail again. I have found abundant evidence in the past year that the current or energy on the pipe, no matter how small, will leave the pipe for a soil which has certain elements in it, and electrolysis is begun immediately.

It has been less than a year since I sent your members ample evidence from all over the country of the destructiveness of the electrical current. Cities that reported no evidence a year ago are now reporting serious destruction. Besides, I do not think there is a member of your Association who, at this time, would question the destructiveness of the current, or the proposition that the street car company, having created the current, is certainly bound in all equity and law to provide for its safe return without damage to the property of others.

DESCRIPTION OF ILLUSTRATIONS.

Plate I. *Fig. 1.* — Wrought-iron gas service pipes removed from beneath street car tracks, Richmond, Va.

Fig. 2. — Four-inch cast-iron water main removed from Seventh Street, Richmond, Va.

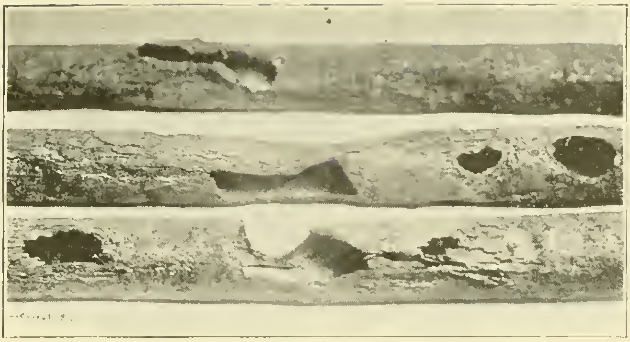

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

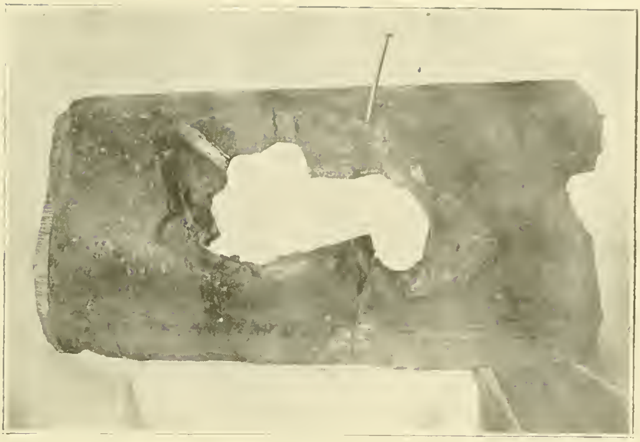

Fig. 1

Fig. 2.

Fig. 3.

Fig. 3. — Eight-inch pipe taken out by Manufacturers' Natural Gas Company in front of power house, West Washington Street, Indianapolis, Ind. In places holes could be punched through the pipe with an umbrella.

Fig. 4. — Service pipe in park, not near street car line, St. Louis, Mo.

PLATE II. *Fig. 1.* — Pipe taken up at St. Louis, Mo. At upper right-hand corner of picture the pipe has been cut with a knife. Also a nail has been driven into the pipe.

Fig. 2. — Four-inch valve destroyed by electrolytic action, not far from power house.

Fig. 3. — Eight-inch pipe removed beyond Belt Railroad, at a point a mile from car line, by Indianapolis Gas Company. The street car tracks cross the pipe line in such a way that a triangle is formed, of which the pipe line forms the base; and this is the direct and shortest route to the power house.

SUPPLEMENT.

On December 22, 1900, Judge Carter of the Superior Court overruled the defendant's demurrer to the complaint in the case of the Manufacturers' Natural Gas Company against the Indianapolis Street Railway Company for $50,000 damages for injuries to the Gas Company's pipes through electrolysis. The court holds that the cause of action is good, and practically asserts that damages will lie. The opinion in part follows: —

"The method in use by the defendant in operating its cars results in serious injury, and, in some cases, to the destruction of plaintiff's pipes. The defendant can, by the use of an approved appliance at reasonable expense, operate its cars so as to avoid injuring the plaintiff's pipes. The plaintiff cannot, by any known method, protect its pipes from injury.

"The plaintiff owns its pipe line laid in the street by legal authority. Such pipe line is property within the meaning of the constitution and laws. It is subject to taxation; it may be sold and purchased as other property. The Street Railway Company seizes on these pipes and makes use of them, as a conductor for its return current, and in so doing greatly injures and, in some instances, wholly destroys them, and this is done under a claim that it is performing a public service under authority of law. Is not this a taking of private

property for public use and for which just compensation must be made?

"I do not see that the fact that the Street Railway Company's tracks, poles, and wires may have been placed in the street before the plaintiff's pipes were so placed can make any difference unless it should be shown that when it placed them there it knew of the injuries to which they would be subjected.

"The city could not and did not grant a monopoly of the street either to the defendant or its predecessor; and when the tracks, poles, and wires were placed in the street, the Railway Company knew that gas and water pipes might be laid in the street at any time, and it acquired its rights to run an electric road subject to that fact, and all the consequences that might follow. The plaintiff is not a trespasser, but occupies the street lawfully, and while there, its property is taken by the Street Railway Company as a consequence of its operations.

"Justice Brown, in the case in 42 Fed. Rep. 279, states that the substance of all the cases which he has examined is that 'where a person is making lawful use of his own property or of a public franchise in such a manner as to occasion injury to another, the question of his liability will depend on the fact whether he has made use of the means which, in the progress of science and improvement, have been shown to be the best.'

"A street railway company is not, however, bound to adopt the latest invention, nor to adopt any before its utility and practicability have been demonstrated by use.

"The case made by the complaint in this cause seems to meet the requirement contained in Judge Brown's statement.

"According to the allegations of the complaint, the defendant has failed to adopt an approved appliance which could be done at a reasonable expense, and when by so doing the injuries complained of could be avoided.

"I cannot see any difference in principle between a case in which liability attaches from a failure to adopt the best-known device, and one where there is a failure to adopt any device whatever, when there are devices by which the injury could be avoided, and the utility of which has passed the point of being a mere experiment.

"These questions are new, and we are without precedent in decided cases for our guidance; but as these new questions arise, the administration of the law should keep step to the new situations arising in

the march of scientific invention and improvement, not by inventing new legal principles, but by the expansion of old and well-recognized principles of law and equity so as to meet and cover the new situation. It would be a reproach to our system of jurisprudence and the administration thereof if a situation could arise in which large and material injury should be done to legal rights and destruction caused to property, and the law be powerless to apply a remedy.

"Take the situation in this city; the number and size of the cars propelled through our streets by electricity is ever rapidly on the increase. Suburban lines are coming into the city from every direction, with cars larger than ever before used on the streets, and the currents of electricity which now are, or soon will be, discharged into the earth of the streets are very large; and if it be true, as claimed in some of the cases which I have examined, that these currents not only attack gas and water pipes, but the steel frames of tall buildings as well, and that such steel frames may be deteriorated and weakened so as to imperil such buildings, is there no remedy in the law to prevent it, or to compel the Street Railway Company to control its return current, when it is conceded that it is reasonably in its power to do so?

"Where a corporation is exercising a public franchise, and does so in such a manner as to cause actual material injury to legal rights and destruction of property, when at reasonable expense, by the adoption of well-known and approved appliances, the injury could be avoided, and the person injured is powerless to prevent or guard against such injury, then I think it must be held to be negligence in the use of its franchise on the part of such corporation not to adopt such approved appliances.

"The destruction of the plaintiff's pipes so as to permit gas to escape and cause destruction to life and property cannot be said to be mere annoyances, inconveniences, or incidental damages. It has been held in New York, in the case of Siebrecht *v.* East River Gas Company (47 N. Y., Supp. 262, 1899), that the Gas Company is liable in damages sustained by the action of gas which escaped from the company's pipes from leaks caused by electrolysis; to be subjected to such a liability cannot be considered a mere incidental damage.

"For the foregoing reasons I think the complaint states a good cause of action, and the demurrer is therefore overruled."

A REPORT ON TRIAL OF 30 000 000 GALLON PUMPING ENGINE AT THE CHESTNUT HILL HIGH-SERVICE STATION OF THE METROPOLITAN WATER WORKS, MADE MAY 1 AND 2, 1900.

BY WILL J. SANDO, RECENTLY SUPERINTENDENT OF PUMPING STATIONS, METROPOLITAN WATER WORKS.

[*Read November 14, 1900.*]

The test was conducted by the engineering department of the Board, represented by Dexter Brackett, engineer of the Distribution Department; Will J. Sando, superintendent of Pumping Stations; and the E. P. Allis Company, represented by Arthur J. West, M.E.

DESCRIPTION OF PLANT.

The engine was designed and built by the E. P. Allis Company, of Milwaukee, Wis. The contract was signed January 1, 1897, and the engine first started in December, 1898. It is of the vertical, triple-expansion, self-contained type, with three single acting outside packed plungers, having at contract speed (about 17½ revolutions per minute) a capacity of 30 000 000 U. S. gallons in twenty-four hours. The pump plungers are placed directly under the steam cylinders and rigidly connected with the steam pistons.

The steam inlet and exhaust valves for the high pressure cylinder and the inlet valves for the intermediate pressure cylinder are of the Corliss type; the exhaust valves for the intermediate pressure cylinder and the inlet and exhaust valves for the low pressure cylinder are of the poppet type. All valves receive their motion from a lay shaft, which is driven from the crank shaft by means of two connecting rods. The cut-off on the high pressure cylinder is controlled by an automatic centrifugal governor and is also adjustable by hand. On the intermediate pressure cylinder the cut-off is adjustable by hand and on the low pressure cylinder the cut-off is fixed.

The cylinders are jacketed on barrels. All valves are placed in the cylinder heads and jacketed only by the working steam.

There are receivers, fitted with copper reheating coils, between the high and intermediate pressure cylinders and the intermediate and low pressure cylinders. The volumes are respectively four and one-half times, and two and three-quarters times, the volumes of the preceding cylinders.

The system of steam distribution through the jackets and receiver coils is as follows: The high pressure jacket is supplied with steam from the main steam pipe at the same pressure as the steam at the throttle valve; the first receiver coil is supplied from the high pressure jacket outlet, and the intermediate pressure jacket is supplied at a reduced pressure from the first receiver coil outlet. There is also discharged into the intermediate pressure jacket the water drained from the first receiver coil inlet, a $\frac{1}{4}$-inch pipe and globe valve being provided for this purpose. From the intermediate pressure jacket the mixture of steam and water enters the second receiver coil, and from here is trapped and discharged into the bottom of the second receiver, and is then trapped to waste. The low pressure jacket is supplied with steam at a reduced pressure from the working side of the first receiver. The connection is taken out at the bottom of the receiver to prevent the water of condensation from entering the intermediate pressure cylinder. To insure circulation in the low pressure jacket there is a $\frac{1}{4}$-inch free pipe connection from the top of the jacket to the working side of the second receiver. The drain from the low pressure jacket is trapped to waste. The drain from the separator is discharged into the top of the first receiver. To keep steam on the low pressure jacket when the engine is not running, a by-pass pipe is provided on the trap which drains the second receiver coil, so that, instead of discharging into the second receiver, the mixture is discharged into the low pressure jacket.

The surface condenser contains 2 000 square feet of cooling surface. The circulating water is taken from and returned to the suction pipe. Directly on top of the condenser there is an exhaust heater which contains 300 square feet of heating surface. The boiler feed pump is attached to and driven by the main engine. The feed water is taken from the out-board circulating pipe on the condenser, and on its way to the pump suction passes through the heater. The air pump and the air compressor for charging the discharge air chambers are attached to and driven by the main engine.

Each pump is composed of five principal castings, which are located at right angles to the longitudinal center line of the engine.

On one side there is a suction valve chamber, and on top of this a suction air chamber. On the opposite side there is a discharge valve chamber, and on top of this a discharge air chamber. The suction and discharge valve chambers are connected by the plunger chamber. The suction, discharge, and plunger chambers rest on and are bolted to a masonry foundation, and the engine bed-plate rests on and is bolted to the top of the suction and discharge air chambers, thus forming a self-contained structure.

The three pumps are connected longitudinally by the suction pipe on one side and the discharge pipe on the other. The pump valves are five eighths of an inch thick and made of the best grade of medium rubber. The valve seats are made of composition, and are mounted, in groups of thirty-five, on cages which can be easily removed from the chambers. The free waterway through each set of suction and discharge valve seats is 121 per cent. of the area of the plunger.

Steam was furnished by a double furnace Belpaire boiler, designed by E. D. Leavitt, M.E., and built by the Lake Erie Boiler Works. Each furnace is equipped with an American mechanical stoker. Forced draft for the stokers is supplied by a Sturtevant blower outfit. The escaping gases pass from the boiler around the tubes of a Green economizer. The feed water is pumped through the tubes of the economizer on its way to the boiler.

METHOD OF CONDUCTING TRIAL.

The contract provided that the engine should perform a duty of 150 000 000 foot pounds for each one thousand pounds of commercially dry steam used by the engine and any auxiliary pumps supplied by the contractor, steam containing less than one and a half per cent. of entrained water, as determined by calorimeter measurement, to be considered as commercially dry steam ; the work performed by the engine to be based upon plunger displacement.

As the contract requirement for duty was based upon the quantity of steam used by the engine, great care was taken to accurately determine this amount. All connections between the boiler which supplied steam to the engine and the other boilers in the station were either broken or closed with blank flanges. All condensed steam from the low pressure cylinder was discharged by the air pump into a wrought-iron tank, from which it was drawn into a second

or weighing tank, and from there it was discharged into a third tank, from which the supply for the boiler was taken. Wrought-iron tanks resting on platform scales received the condensed steam from the separator, the jackets of the high and intermediate steam cylinders and receiver coils, and the jacket of the low pressure cylinder. The condensed steam before entering the weighing tanks was passed through coils submerged in cold water, in order to prevent loss from evaporation.

The water from all of these tanks, after being weighed, was discharged into the large suction tank, and was from there forced into the boiler by the feed pump attached to the main engine. The supply to the boiler was regulated by means of the by-pass, through which the discharge from the feed pump could be returned to the suction tank.

During the test all steam used by the stoker cylinders and blowing engine and the economizer engine was supplied by another boiler, so that if there had been no leakage from the boiler, economizer, and piping, the quantity fed into the boiler would have agreed with the quantity received from the engine and separator. In order to determine the amount of leakage from the boiler, economizer, and piping, a test was made on April 28 and 29. For twenty-four hours the steam pressure in the boiler was maintained at 190 pounds, the throttle valve at the engine was closed, and hourly observations were made of the condensed steam from the jackets and separator and of the elevation of the water in the boiler. Sufficient water was pumped into the boiler to bring the water level to the same elevation at the end of the twenty-four hours as it was at the beginning, and it was found that the leakage from the boiler, economizer, and piping was at the rate of 46.35 pounds per hour.

The steam pressure at the engine was determined by means of a mercurial gage connected at the main throttle valve, and readings of this gage were taken every fifteen minutes throughout the trial. The elevation of the water in the pump well was determined from the average of readings of a float gage taken every fifteen minutes during the duration of this test. The pressure of water in the force main was determined from the average of readings taken every five minutes of a carefully calibrated mercurial gage connected with the force main near the discharge from the engine. The revolutions of the engine were observed and recorded every fifteen minutes. The Peabody calorimeter was used for measuring the entrained water in

the steam; four samples were taken during the trial. The steam used by the calorimeter was condensed and weighed in a tank.

Observations were made and recorded each hour during the trial of the steam pressure in the receivers between the steam cylinders, the vacuum in the condenser, the temperatures of steam at the throttle valve and at the inlet and outlet of each steam cylinder, the temperatures of water in the drains from the receiver and the low pressure jacket, the temperature of water discharged from the air pump, of water entering and leaving the condenser and in the several weighing tanks, of air in the engine room, and of the outer air.

In the boiler room a record was made of the weight of coal fed to the hopper of the mechanical stoker during each hour. The level of the water in the boiler, the steam pressure, the draft and the temperature of water entering and leaving the economizer, and of the air in the boiler room were observed and recorded every fifteen minutes. The temperatures of the gases before and after passing the economizer were observed every thirty minutes. A sample of flue gas was taken and analyzed every hour, and gages recording the pressure of air in the ash pit and suction in the flue at end of boiler were read at frequent intervals.

As the contract duty was based upon steam consumption and not upon the amount of coal used, it was not deemed advisable to attempt to begin the test with a new fire under the boiler, or to draw the fire at the close of the trial. Fires were cleaned about two hours before the test began, and once during the twenty-four hours, which is the regular practice in operating the station. The condition of the fires at the beginning and at the end of the test was as nearly the same as could be determined by the careful inspection of three persons; and as the quantity of coal fed to the boiler during the last four hours was above the average during the remaining portion of the time, it is thought that the recorded weight very closely represents the actual quantity burned during the twenty-four hours.

All scales for weighing water and coal were tested and sealed by the city sealer of weights and measures immediately before the trial. All indicator springs were tested a few days before the trial. All thermometers were tested. All pump valves were tested for leakage and found to be practically tight.

Indicator diagrams from all the steam cylinders and pumps were taken every hour. All the indicators, six on the steam cylinders (one on either end), and three on the pumps, were electrically connected in

such a manner that nine diagrams were taken simultaneously, each of which represented the average pressure in the cylinder or pump for one minute. The pencil friction of the indicator was obviated by a current breaker, which gave the pencil an intermittent instead of constant contact, and formed the card by a series of dots. As the pencil went over each card 17.54 times the appearance is almost a continuous line. While the indicator diagrams were being taken, five-second observations were made of the pressure in the force main.

The average friction of the engine for the twenty-four hours of the trial was determined from the average of the differences between indicated horse-power and the actual work done during times while the diagrams were being taken.

The coal used during the trial was the Loyal Hanna, Sonman Shaft, run of the mine coal, in regular use at the station. The coal was tested for its calorific power, and the thermal units given in table represent the value of one pound as actually used.

GENERAL DATA.

Principal Dimensions of Engine.

1.	Diameter H. P. cylinder (nominal)	30 in.
2.	Diameter I. P. cylinder (nominal)	56 in.
3.	Diameter L. P. cylinder (nominal)	87 in.
4.	Cylinder clearances:	
5.	High pressure	1.35 per cent.
6.	Intermediate pressure	0.55 per cent.
7.	Low pressure	0.45 per cent.
8.	Diameter of plungers (nominal)	42 in.
9.	Stroke of pistons and plungers (nominal)	66 in.
10.	Diameter suction and discharge pipes	48 in.
11.	Diameter fly wheels (2)	20 ft.
12.	Weight of each wheel	50 000 lbs.
13.	Revolutions per minute for capacity	17.5
14.	Speed per minute	192.5 ft.
15.	Diameter of crank shaft journals	18 in.
16.	Length of crank shaft journals	24 in.
17.	Angle of cranks	120°
18.	Diameter H. P. and L. P. crank pins	9 in.
19.	Length H. P. and L. P. crank pins	11 in.
20.	Diameter I. P. crank pin	14 in.
21.	Length I. P. crank pin	11 in.

Principal Dimensions of Boiler Plant.

22. Boiler diameter ......90 in.
23. Boiler length (over all) ......34 ft. 4 in.
24. Number of tubes 201
25. Diameter of tubes ......3 in.
26. Length of tubes ...... 16 ft
27. Heating surface ......2 849 sq. ft.
28. Inside area of tubes ......8.49 sq. ft.
29. *Grate, length (each) ......7 ft.
30. *Grate, width (each) ......4 ft. 6.75 in.
31. Grate, area (2 furnaces) ......63.875 sq. ft.
32. Ratio of heating to grate surface ......44.6 to 1
33. Ratio of grate to inside area of tubes ......7.52 to 1
34. Economizer heating surface outside of tubes ......1 680 sq. ft.
35. Height of stack ......150 ft.
36. Inside diameter of stack ......5.5 ft.

Measured and Calculated Dimensions.

	High Pressure.		Intermediate.		Low Pressure.	
	Top.	Bottom.	Top.	Bottom.	Top.	Bottom.
37. Diameter steam cylinders measured at shops	30.005	30.005	55.984	55.984	87.009	87.009
38. Diameter steam cylinders at temperature due to actual working conditions (calculated), inches	30.05	30.05	56.04	56.04	87.07	87.07
39. Area steam pistons under working conditions, square inches ..	709.22	675.62	2466.53	2432.93	5954.26	5920.66
40. Scale of steam indicator springs	119.80	118.70	19.60	19.65	9.64	9.78

	High Pressure.	Intermediate.	Low Pressure.
41. Stroke of pistons and plungers, engine running, inches	66.000	65.9375	65.96875
42. Stroke of pistons and plungers, engine running, feet	5.500	5.4948	5.4974
43. Circumference of plungers, feet	11.004	11.0025	11.0010
44. Diameter of plungers, feet	3.5027	3.5022	3.5017
45. Area of plungers, square feet	9.63588	9.63325	9.6306

* American mechanical stokers used under boilers with forced draft.

	High Pressure.	Intermediate.	Low Pressure.
46. Area of plungers, square inches.......	1 387.5667	1 387.1880	1 386.8064
47. Displacement of one plunger per revolution (water 62.4 lbs. per cubic foot), cubic feet.................	52.9973	52.9328	52.9433
48. Number of steam piston rods..........	2.	2.	2.
49. Diameter of steam piston rods, inches..	4.625	4.625	4.625

TRIAL DATA.

50. Date of trial ....9.15 A.M., May 1, to 9.15 A.M., May 2, 1900.
51. Duration of trial.......... ....24 hours.

Average Pressures.

52. Steam at boiler ....187.37 lbs. per sq. in.
53. Steam at throttle ....185.47 lbs. per sq. in.
54. First receiver.................................30.85 lbs. per sq. in.
55. Second receiver...............................−3.31 lbs. per sq. in.
56. Vacuum ....13.80 lbs. per sq. in.
57. Vacuum.......................................28.16 in. mercury.
58. Barometer.................................... 14.63 lbs. per sq. in.
59. Barometer....................................29.85 in. mercury.
60. H. P. jacket ....185.47 lbs. per sq. in.
61. I. P. jacket ....73.40 lbs. per sq. in.
62. L. P. jacket...................................4.80 lbs. per sq. in.
63. Draft in ash pit ....1.38 in. water.
64. Draft in flue at end of boiler ....0.47 in. water.

Average Temperatures.

65. Steam at boiler.................................382.95° F.
66. Steam at throttle ....382.15° F.
67. Steam entering H. P. cylinder......................381.34° F.
68. Steam entering first receiver ....275.05° F.
69. Steam entering I. P. cylinder ....278.36° F.
70. Steam entering second receiver......................199.46° F.
71. Steam entering L. P. cylinder.......................198.91° F.
72. Steam leaving L. P. cylinder........................116.41° F.
73. Water from second receiver ....197.45° F.
74. Water from L. P. jacket ....205.07° F.
75. Water discharged from air pump....... ....76.19° F.
76. Water in condenser tank...........................76.19° F.

77. Water in second receiver tank .... 90.44° F.
78. Water in L. P. jacket tank .... 83.88° F.
79. Water in separator tank .... 60.94° F.
80. Water in make-up tank .... 52.67° F.
81. Water entering economizer .... 79.72° F.
82. Water leaving economizer (fed to boiler) .... 154.98° F.
83. Water condenser circulating inlet (water pumped) .... 52.67° F.
84. Water condenser circulating outlet .... 78.79° F.
85. External air .... 51.95° F.
86. Engine room .... 66.50° F.
87. Boiler room .... 83.40° F.
88. Flue gases leaving boiler .... 485.40° F.
89. Flue gases leaving economizer .... 221.90° F.

Data for Head Pumped Against.

90. Average elevation of water in force main above Boston City Base .... 271.856 ft.
91. Average elevation of water in wet well above Boston City Base .... 131.506 ft.
92. Average net head pumped against .... 140.350 ft.

Revolutions.

93. Total revolutions during 24 hours .... 25 539.
94. Average revolutions per minute 17.7354

Useful Work Performed by Engine.

95. Water pumped per revolution (plunger displacement) .... 1 188.454 U. S. gals.
96. Water pumped per revolution (plunger displacement) .... 158.8732 cu. ft.
97. Water pumped per revolution (at 62.4 lbs. per cubic foot) .... 9 913.7 lbs.
98. Total plunger displacement .... 30 351 926 U. S. gals.
99. Plunger leakage .... 38 015 U. S. gals.
100. Plunger leakage .... 317 110 lbs.
101. Water pumped (no allowance for slip) .... 30 313 911 U. S. gals.
102. Net foot-pounds useful work (plunger displacement) .... 35 534 608 420 ft. lbs.
103. Net foot-pounds useful work deducting plunger leakage .... 35 490 102 245 ft. lbs.

Water Fed to Boiler.

104. To suction tank from condenser tank .... 169 819.0 lbs.
105. To suction tank from L. P. jacket tank .... 25 356.5 lbs.
106. To suction tank from second receiver tank .... 5 81.5 lbs.

107. To suction tank from separator tank ....1 933.5 lbs.
108. To suction tank from make-up tank ....3 115.5 lbs.
109. Add for suction tank low at end of test ....10.0 lbs.
110. Add for boiler level low at end of test ....54.0 lbs.
111. Total water fed to boiler ....205 370.0 lbs.

Steam Out of Boiler not used by Engine.

112. Water from separator ....2 019.0 lbs.
113. Steam blown through calorimeter (weighed in tank)...........649.0 lbs.
114. Leakage from whole plant exclusive of engine ....1 112.5 lbs.
115. Total steam out of boiler not used by engine ....3 780.5 lbs.
116. Steam chargeable to engine ....201 589.5 lbs.

Steam Received from Engine.

117. From condenser ....170 427.0 lbs.
118. From L. P. jacket ....25 886.5 lbs.
119. From second receiver ....5 276.0 lbs.
120. Total steam used by engine ....201 589.5 lbs.
121. Average entrainment in steam entering engine, 1.37 per cent ....2 761.8 lbs.
122. Total dry steam used by engine ....198 827.7 lbs.
123. Percentage of total steam used in jackets ....15.45 p. c.

British Thermal Units.

124. Heat of vaporization steam, 200.10 absolute, equals. 843.77 B. T. U.
125. Heat of liquid steam, 200.10 absolute, equals .... 354.64 B. T. U.
126. Heat of liquid discharged from condenser, temperature 76.19° F., equals .... 44.30 B. T. U.
127. Heat of liquid discharged from second receiver, temperature 197.45° F., equals .... 166.15 B. T. U.
128. Heat of liquid discharged from L. P. jacket, temperature 205.07° F., equals .... 173.77 B. T. U.
129. Heat of vaporization steam at boiler, 202 lbs. absolute, equals .... 843.20 B. T. U.
130. Heat of liquid steam at boiler, 202 lbs. absolute, equals .... 355.40 B. T. U.
131. Heat of liquid entering economizer, temperature 79.72° F., equals .... 47.81 B. T. U.
132. Heat of liquid entering boiler, temperature 154.98° F., equals .... 123.28 B. T. U.
133. Heat per pound of moist steam used in cylinder equals 1 142.55 B. T. U.
134. Heat per pound of moist steam used in H. P. and I. P. jackets and receiver coils, discharged from second receiver, equals .... 1 020.70 B. T. U.
135. Heat per pound of moist steam discharged from L. P. jacket equals .... 1 013.08 B. T. U.
136. Heat put into feed water by economizer equals ..... 75.47 B. T. U.

137. Heat put into steam by boiler equals................ 1 075.32 B. T. U.
138. Heat to convert condenser water to steam equals .... 194 721 400 B. T. U.
139. Heat to convert L. P. jacket water to steam equals .. 26 225 100 B. T. U.
140. Heat to convert second receiver water to steam equals 5 385 200 B. T. U.
141. Total heat used by engine .... 226 331 700 B. T. U.
142. Heat contained in one pound of wet coal .... 14 023 B. T. U.

Horse-Power Figures.

143. Average percentage of friction of engine (average of 18 sets of cards)................................	6.71 p. c.
144. Average delivered horse-power (useful work).......	747.785
145. Average Ind. horse-power, H. P. cylinder...........	292.057
146. Average Ind. horse-power, I. P. cylinder............	248.773
147. Average Ind. horse-power, L. P. cylinder	260.739
148. Total Ind. horse-power............................	801.569
149. Average moist steam per I. H. P. per hour..........	10.479 lbs.
150. Average dry steam per I. H. P. per hour............	10.335 lbs.
151. Average B. T. U. per I. H. P. per minute	196.080

Coal and Rate of Combustion and Evaporation.

152. Total coal burned 24 hours	19 612 lbs.
153. Coal burned per square foot of grate surface per hour	12.793 lbs.
154. Coal burned per square foot of heating surface per hour	0.287 lbs.
155. Evaporation per pound of coal, actual conditions, including economizer	10.472 lbs.
156. Evaporation per pound of coal, actual conditions, excluding economizer	9.785 lbs.
157. Evaporation per pound of coal, from and at 212° F., including economizer	12.478 lbs.
158. Evaporation per pound of coal, from and at 212° F., excluding economizer	11.660 lbs.
159. Evaporation per square foot of heating surface per hour	3.00 lbs.
160. Coal per I. H. P. per hour........................	1.02 lbs.
161. Coal per D. H. P. per hour.........................	1.09 lbs.
162. Coal burned 24 hours, for fan, stoker, and economizer engines, as determined by subsequent test	800 lbs.
163. Total coal burned if boiler supplying steam for test had supplied steam to fan, stoker, and economizer engines..	20 412 lbs.

164. Kind of coal, Loyal Hanna, Sonman Shaft.

Duties.

165. Duty per 1 000 lbs. moist steam, deducting plunger leakage (contract basis) .... 176 051 500 ft. lbs.
166. Duty per 1 000 lbs. dry steam, deducting plunger leakage .... 178 497 000 ft. lbs.
167. Duty per 1 000 000 B. T. U. .... 157 002 500 ft. lbs.
168. Duty per 100 lbs. coal, making allowance for coal required for supplying steam to fan, stoker, and economizer engines .... 173 869 000 ft. lbs.

Efficiencies.

169. Efficiency of mechanism .... 93.29 p. c.
170. Efficiency of boiler and economizer, actual .... 85.9 p. c.
171. Efficiency of boiler alone, actual, if economizer had not been used .... 80.3 p. c.
172. Thermal efficiency of engine .... 21.63 p. c.

DISCUSSION.

Mr. R. J. Flinn.* I would like to inquire, in relation to the method of disposing of the jacket water, which seems to be something entirely new, who claims to be the originator of the device. Perhaps Mr. Brackett can tell us.

Mr. Dexter Brackett.† So far as I know, the device was originated by the Allis Company, and I think by Mr. West, their mechanical engineer.

Mr. Flinn. Then I would state that this was published by me several years ago in the New York *Power* and also in the *American Machinist*, and in some of the English and French papers. I first used it, and I sent the drawings to Mr. Reynolds of the Allis Company, and I think probably Mr. West got the idea from that.

Mr. Brackett. That part of it I know nothing about.

Mr. Flinn. If anybody wishes to see it, it is published in the June, 1897, *Power*, on page 20; also in the *English Mechanic* of a later date, the *American Machinist*, and some of the French mechanical papers published about that time.

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* Engineer, Brookline Water Works.
† Engineer, Distribution Department, Metropolitan Water Works.

CAUSE AND EFFECT OF ELECTROLYTIC ACTION UPON UNDERGROUND PIPING SYSTEMS.

BY A. A. KNUDSON, ELECTRICAL ENGINEER, NEW YORK CITY.

[*Read December 12, 1900.*]

Your President having honored me with an invitation to read a paper before you pertaining to electrolysis, we have thought, in view of what is now generally known on the subject, that such a paper, to be of interest, should deal with the latest discoveries in the state of the art, which refer to the cause and effect of straying railway currents upon water mains, gas mains, or other underground structures.

We have therefore gleaned a few incidents and facts which have come under our personal notice in a number of recent investigations, which we will present, in the hope that they may be of some value, and additional light may be thrown on this important subject.

With a view of treating the subject with some degree of system, we shall consider it under the following heads; namely: —

1. Cause of deflection of currents from well-bonded tracks to water mains.
2. Acute points of deflection of currents to water mains.
3. Effect of joint resistance on water mains.
4. Effect upon water mains in a positive district.

It will be understood that in this paper "negative" districts are where the general tendency of the electric current is to enter the water mains; and "positive" districts are where the general tendency of the electric current is to leave the water mains; the damage occurring under the positive condition.

Under the first heading, namely: —

1. *Cause of deflection of currents from well-bonded tracks to water mains.*

Where the rails are used for the return current, as is the case in the single wire trolley systems, they must of necessity be in contact with the earth, which has more or less moisture; in the same earth a short distance away are located water mains and other structures;

this intervening earth is the connecting link between the railway tracks and water-piping systems, through which current passes from one to the other. It is not surprising, therefore, that the interlacing network of the piping system of a city under such conditions should offer a good electrical return for the railway current, even when the rails are most perfectly bonded. It often happens, where there are large mains under the streets, that they constitute electrical conductors whose area of cross section far exceeds the cross section of the rails; in such case, even if the rails were electrically welded, or cast welded, there would still be more or less deflection of current to the mains. We have noticed this where we have made tests in the neighboring cities of Providence, R. I., and Pawtucket, R. I. On a line in Providence, so welded, the readings ranged from 4 to 8 volts negative, and in Pawtucket, from 0.5 positive to 4.4 volts negative. I presume the cast weld joint, when well placed, makes as good an electrical contact between the rail ends as any of the specially contrived bonds; but none of them, not even a continuously solid rail, can entirely confine the currents to the rails. We have made many tests at rail joints, and have found in the case of many well-bonded rails a difference of potential of not over 0.003 volt. This is coming closely to the conductivity of the rail itself, and if such a condition could be continuously maintained in all parts of a railway system, the rapid destruction of water mains by electrolysis would be materially reduced. Such a condition, however, I believe to be practically impossible. In the investigations of some fourteen different cities, some of which have the best modern construction of electric railways, using the rails as a return, I have found quite high differences of potential between rails and mains at different places, and electrolytic damage upon the pipes in many cases, where uncovered.

A well-bonded track return, therefore, should not be accepted as a cure for electrolysis.

2. *Acute points of deflection of currents to mains.*

These inevitably result from the use of the "rail return." Such points here and there in a city generally go unnoticed until the effect is shown in the bursting of service pipes or mains caused by electrolysis, or until some one has been called in to investigate. The high differences of potential which generally cause such acute deflection are often due to broken or worthless rail bonds at switches and crossings. These are found in every city, more or less. Sometimes we find other causes for these escapes, as, for instance, in one case

where new rails had been placed on a line, a few old rails were left at the terminus; the result, a difference of potential of 42 volts; where the new rails left off and the old commenced, a high reverse (positive) reading.

I have found differences of potential at the joints of rails ranging from tenths of a volt as high as 25 volts. Such conditions mean practically "open circuit" in the rail return, and generally corresponding damage *somewhere* to the water mains by electrolysis.

One exaggerated cause of current deflection to the water mains is the use of rail chairs in track construction, of which there are still many in existence in various cities at the present day. Examples of these were found in three cities where I have investigated; namely, Peoria, Ill.; Reading, Pa., and Pawtucket, R. I. On some of the lines in those cities the chairs have since been removed. In every case, on lines so constructed, the voltmeter showed high readings. This is largely attributed to their being placed necessarily deep in the ground and to the large amount of surface contact which they present to the earth.

Plate I, Fig. 1, shows some chairs which have been removed from street railway track. It will be seen that the two flanges or legs which are spiked to the ties at their base are in contact with the moist earth both outside and inside when in place, making a convenient outlet for the current from the rails to earth and water mains.

This picture has been shown before in the excellent paper on electrolysis delivered by Mr. D. H. Maury at the convention of the American Water Works Association, held at Richmond, Va., last May, but we show it here as an illustration of one cause of current leaving the rails; the chair at the left, you will notice, has been so reduced by electrolytic action at its base that its original shape is entirely changed, as will be seen by comparison with the one on the right, which is not so damaged.

Fig. 1 is a view of a steam railroad grade crossing, on the line of the Reading & South Western (electric) Railway, at Reading, Pa. This is another illustration of exaggerated deflection of current from rails to water mains; this drawing, which was prepared from photographs (with the exception of the pipe, which is shown for illustration), shows not only the exact construction of the crossing, but the direction of current into and out of the water main, at each side of the crossing.

The voltmeter survey showed that the water main was negative to

the rails through the street in which the cars passed, and as high as 9 volts at the east side of this crossing, and positive on the west side to 6.5 volts. Suspecting that the cause of the jump into and out of the pipe in that short distance was defective bonding on the crossing, we made tests there, and found that scarcely one of the short pieces of rails of the trolley tracks had any electrical connection with another. In a number of tests made between the ends of these parts of rails with the voltmeter, the lowest reading was 4 volts, and the highest 25 volts; the high differences of potential, however, being due to the movements of the cars; but they all showed the condition of *open circuit* in the rail return.

In making tests near and in front of the power station, which was about one thousand feet further west of this crossing, we were struck with the high readings, which ranged from 8 to 26 volts positive. We have often noticed before this that where such high differences of potential are found there is generally a bad break somewhere in the rail return, which can be found if carefully looked for; in this case, we were looking for just such an opening in the tracks, but did not expect to find it on a steam railroad crossing, as previously, where we have made tests on steam track crossings, they have been found in fairly good order.

You will notice in this case the water main acts as a bridge to carry the trolley current past the break in the rails; the current returns again to the rails after passing the break. This is strictly in accordance with electrical action, where two paths are offered for

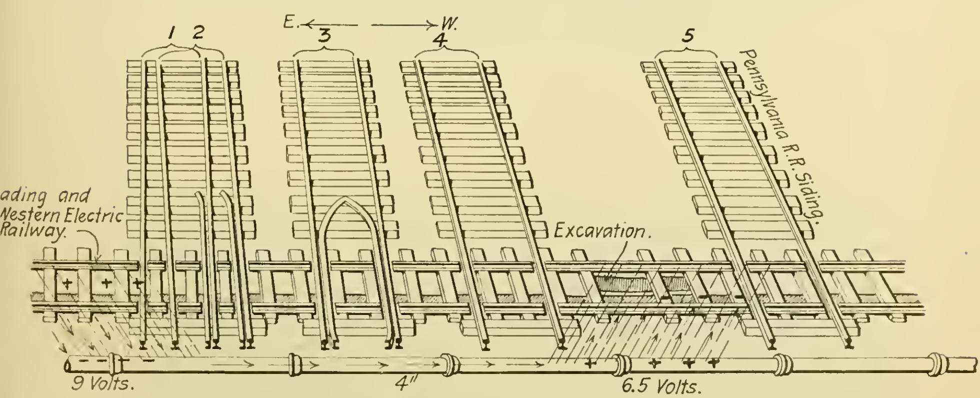

FIG. 1.—CONDITIONS ON CHESTNUT STREET NEAR POWER HOUSE, READING, PA.

the current; if one fails, the other will assume its load, if of sufficient conductive capacity.

The next picture, photograph No. 3 (Plate II, Fig. 1), shows the condition of the water main at the excavation just beyond this crossing. The hole at the left in this piece of pipe is where the pipe burst when we were trying to find how deep in the cast iron the soft graphite — effect of electrolysis — extended; we soon found that it extended entirely through the pipe at this place, and also at another place at the other end of this piece of pipe, while at other places it was badly damaged.

In this particular case where the *cause* is shown of current deflection to the water main, its return to the rails, and the consequent destruction of the pipe, there appears to be no link in the chain missing, from *cause* to *effect*.

There is another point to be considered, where an open circuit in

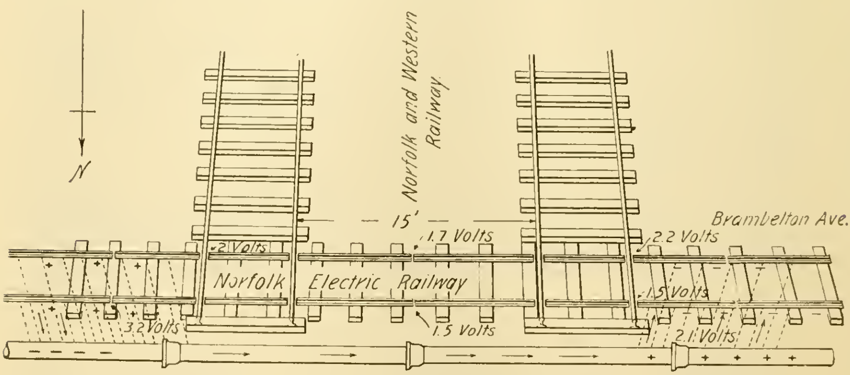

FIG. 2.—CROSSING OF ELECTRIC AND STEAM RAILROADS, NORFOLK, VA.

the rails exists over steam track crossings; and that is the danger of a trolley car becoming "stalled" over such crossings and the possibility of a bad accident. This is possible, particularly in dry weather, when the tracks on the crossing would have little contact with the earth; and this may have been the cause of some accidents which have happened in the past on steam railroad crossings, where trolley cars have been run down.

To show that these conditions found on the crossing in Reading are not exceptional, we show in Fig. 2 a view of another one, found at Norfolk, Va. In this case you will notice there are five openings

PLATE I.

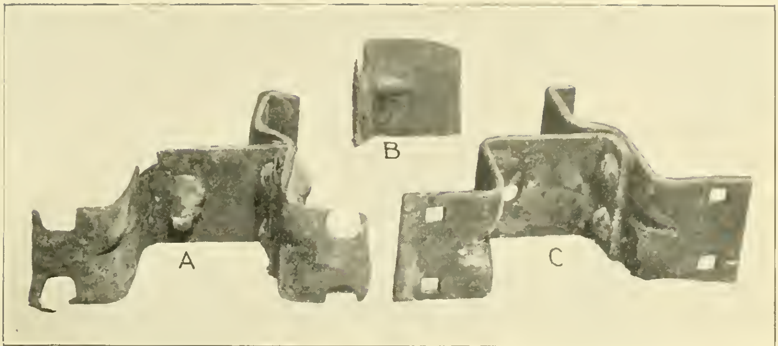

Fig. 1. — Rail Chairs removed from Street Railway Track.

Fig 2. — Effects of Electrolysis on Bell of 6-inch Pipe, Providence, R. I.

Fig. 3. — Destruction of Water Pipe by Electrolysis. Providence, R. I.

FIG. 1. — WATER MAINS TAKEN UP NEAR RAILROAD CROSSING. READING, PA.

between the rails according to the voltmeter, the readings of which are shown at each place where taken; three on one side of the track and two on the other. These openings cause the current, as in the former case at Reading, to pass down to the water main from the rails at one side of the crossing and up again from the main to the rails on the other side, creating a condition destructive to the water mains.

Both of these crossings, the one in Reading and the other in Norfolk, show plainly that such conditions can exist for a long period of time unknown to either the city authorities, the steam railroad companies, or even the electric railway company in any city in this country, and are not only ruinous to the water mains, but a menace to public safety.*

3. *Effect of joint resistance on water mains.*

This part of the subject we think is fully as important as any other, for the reason that it affects a larger area in the piping system of a city; and although of slower action than the more noticeable effects found in the positive districts, it is important as showing that the mains are being aged and damaged, while being put to a use entirely foreign to what they were intended for. The shunting of the current around the joints, either through the moist earth on the outside or through the water on the inside, owing to the resistance of the joint, is the cause of pitting or softening of the metal on the high potential side. We find evidence of the current shunting the joints of pipes more or less in every city where we investigate; the following views will illustrate this joint action clearly.

Plate I, Fig. 2, is from a photograph of a piece of six-inch pipe removed from a street in Providence, R. I., and shows the action of electrolysis, both upon the outside and inside; this we think is a good illustration of the action of the shunting current. Several of the outside indentations on the rim of this bell, and also at many other bell ends of pipe which were taken up in this street, showed the presence of graphite, — a sure evidence of electrolysis under such conditions. The inside corners of this and several other pieces were easily shaved down to a depth varying from one eighth to three sixteenths of an inch, as shown in the picture.†

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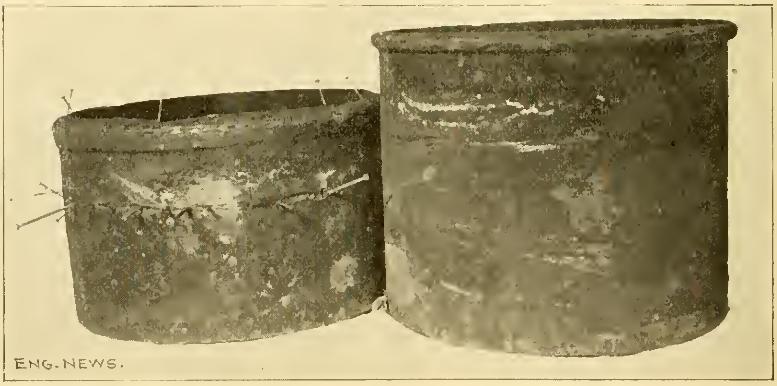
* I am informed that these two crossings have been put in good order since the reports were made.

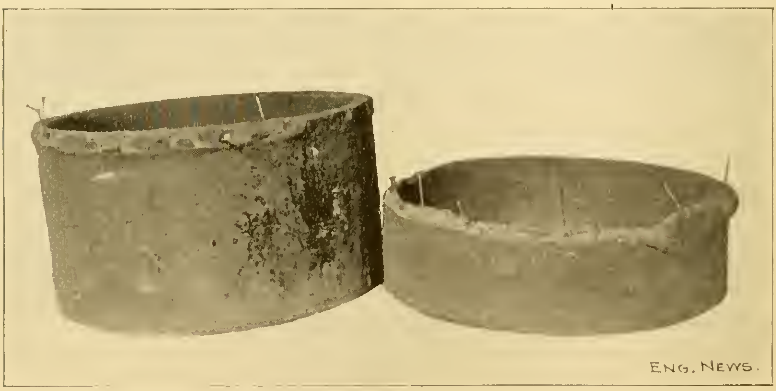
† Since this paper was presented to the New England Water Works Association a striking example of the effect of joint resistance has been published on pages 66 and 67 of *Engi-*

neering News of January 24, 1901, by Mr. D. H. Maury, consulting engineer, with cuts, which are reproduced herewith. He says:—

"Within the last year the writer has never failed to find some evidences of electrolytic action on the mains in Peoria wherever their joints have been examined by him, no matter whether in the positive or negative district. The photographs, Figs. 3 and 4, show examples of pitting in 16-in. pipes which were removed in the spring of 1900. There were in all nearly 1 000 feet of this pipe, which was about two miles from the power station, and ran off at right angles to the tracks. It was always negative to the rails, and the current flowed along it from the spigot end of one pipe into the bell end of the next. No pits could be found anywhere on this pipe except near the positive side of each joint, but the spigot end of every single pipe was pitted, either on the inside or outside or both, where the current left it.

"These photographs furnish another striking instance of electrolytic pitting in the negative district, and show the danger to which an entire piping system is exposed when current is allowed to flow along the mains, a condition that cannot be avoided if the single trolley system is continued."





FIGS. 3 AND 4.—VIEWS SHOWING ELECTROLYTIC PITTING ON PIPES OF PEORIA WATER CO.

4. *Effect upon water mains in a positive district.*

I presume that all present have seen in one form or another the destructive effect of electrolysis upon water mains and service pipes, and very likely have experienced such damage to the property in their charge.

We shall not take up the time, therefore, in showing a large number of pictures of cast-iron pipe destroyed by electrolysis, but will show three, each one having some special reference.

No. 1 of Plate II, Fig. 1, shows sections of pipe taken up at Reading near the power station of the Reading & South Western Railway Company; these were removed previous to the investigation, and perhaps were an incentive to our being called there. The destruction of this pipe, as you will note, is complete.

No. 2 of the same figure is interesting from the fact that this piece of pipe had only been down about one year; it is apparent from the photograph that it was nearly destroyed, and shows what short work electrolysis will make of cast-iron pipe when the conditions are favorable.

Plate I, Fig. 3, is from a photograph of pipe taken from Traverse Street, Providence, in October last, and shows a complete case of electrolytic destruction. Mr. Otis F. Clapp, the city engineer, who kindly furnished this photograph, says that he had two other excavations made about twenty-five feet each side of where this pipe was taken out, but found nothing serious in the way of damage; this goes to show that it is not always possible to accurately locate the points where the most damage is occurring. Sometimes it is discovered at the first attempt, and then again not until the second or third, and perhaps not at all at the precise openings made.

Usually the principal positive districts in a city are in the vicinity of the power stations, but it often occurs that for various reasons positive conditions are found in negative districts.

One or two cases in point may be mentioned: In Reading, Pa., a pipe was uncovered where the voltmeter readings between hydrant and rails were but 0.7 of a volt negative. We found electrolytic pittings ranging from one eighth to one fourth of an inch in depth scattered all over the upper surface of the pipe; and on further investigation it appeared that the pipe at this point *had been positive* to the rails before the change to new track was made, and the positive condition was now reversed to a negative by the change at this point, and the trouble shifted to another point further down the line, where a high positive reading was found.

Let us take another case: At Norfolk, Va., there was a trestle about one thousand feet long over a marsh, upon which the electric cars ran. Near one end of this trestle the voltmeter readings were positive, amounting to upwards of four volts. An excavation revealed the fact of one large indentation or pitting filled with graphite on the rim of a bell, nearly one half an inch in depth and about three fourths of an inch in diameter; other pittings to a lesser degree were also found at other places on this pipe. In looking about for a cause for this positive effect in a negative district, we examined the rails over the trestle and found only six bonds, by actual count, the balance having strayed or been stolen.*

Many similar cases could be related which we have met in our experience, but we think this point of positive conditions in a negative district will be fairly well understood. It will be seen from all this that railway current, after leaving the rails for the water or gas mains, is entirely *out of control*, and will roam throughout the piping systems of a city, causing damage at unknown places, as well as at points discovered through the bursting of pipes or through investigation.

A current having once entered the piping systems of a city is just as much beyond control as a runaway horse; both may be responsible for loss of life as well as damage to property.

These straying currents often take peculiar paths in selecting their routes back to the power stations.

In New York we find currents straying over the Brooklyn Bridge, some going north through the piping system of Manhattan, crossing the East River back to the power station in Brooklyn; other currents go south towards the Battery, and take the river bed or cables to the South Brooklyn power station. In Providence we find them taking a short cut from the positive district on the east side of the Providence River across that river to the power station on the west side. In Pawtucket they find their way into the Blackstone River and follow that stream to the power station. And it is not surprising that the various underground piping systems should act as returns for the current in place of the rails. Let us consider for a moment what sort of a conductor the rails of a track make. We find in a mile of single track of 30-foot rails, 352 joints; counting switches and crossings, there would easily be 400 joints to the mile, or one

* Since the Norfolk report was made, the rails on this trestle have been newly bonded, and a re-survey shows the conditions much improved.

joint to about every thirteen feet; if this so-called conductor were in the shape of a wire placed on poles, its removal would be compelled through ridicule alone, if through no other cause. These 400 joints which are covered up in the ground are continually subject to corrosive action, impairment of electrical contact by traffic over the rails, and breakage of bonds; and consequently a continual increase of resistance is going on, which means a corresponding increase of flow of current towards and through the piping systems. The escape of current to water and gas mains would be bad enough if the rails were continuously perfect conductors; as a matter of fact they are not, and a continuously perfect conductor in a rail return is practically impossible, owing to the conditions stated. Rail bonds *will* become corroded and broken in course of time, in many parts of the system; and on most electric railways such breaks will long go unnoticed.

Partial relief may be obtained at acute points by careful attention to the track returns; but it is apparent that the injury to water mains will continue so long as one side of the railway circuit is in contact with the earth, and any part of the current can find its way into the water pipes.

A complete metallic circuit entirely insulated from the earth is the only real remedy; such a system has been in successful operation for years, overhead or underground, in Cincinnati, New York, Washington, and the District of Columbia. Nothing stands in the way of its general adoption except the hostility of the electric railway companies and their political influence in municipal affairs.

City ordinances designed for the purpose of protecting the water mains are often liable, if care is not used, to place a municipality in an unfortunate position in this respect, from the fact that they may be led to accept some scheme intended as a cure or partial cure for electrolysis; the effect of such ordinances may be to relieve the railway company from liability for future damage, and to throw the responsibility of the cost for any further changes upon the city itself.

It may be known to most of you that damage by electrolysis to water mains throughout the country is on the increase; almost every day we learn of new cases; even those places that six months or a year ago were feeling easy are now quite anxious. One case in point: A water-works superintendent last summer assured me that in his city they had no trouble from electrolysis and did not expect

any. A few days ago the same gentleman was an "anxious inquirer" as to the cost of an investigation. The "trouble" had appeared. In view, therefore, of the accumulating instances of pipes ruined by electrolysis, it is not strange that you water-works people are not feeling quite happy under the surface.

In conclusion, we believe sufficient has been said as to the cause and effect of electrolysis on water mains to place the matter fairly before you, and we will now review briefly some of the points which have been touched upon.

In well-bonded and well-watched track systems, where there is a liberal use of copper for track feeders, differences of potential may be fairly low, and acute points fewer and less aggravated. But it is a very serious thing that even then, millions of dollars' worth of pipe may be having their life shortened by the slower and more widely distributed process of electrolysis, caused by the milder currents, the result of which will have to be reckoned with in the future. The difference is merely one of time.

As to acute escapes, it is these that are mostly responsible for the ruined pipes so frequently found, and which indicate the wider and more serious destruction.

A case in point of acute action is illustrated by the photograph of a piece of pipe, which was shown on the screen, taken from Reading, Pa., shown in Plate II, Fig. 1, and marked "2." This, as has been stated, had only been down about one year, and was shown to be nearly ruined.

Referring to actual breaks in the rail return over steam railroad crossings, the views showing the cause — and a ruined pipe showing the effect — leave but little to add to this part of the subject, except to say we believe it of such importance as to deserve the attention of either State or city authorities; for it seems, in some cases at least, that electric railway companies cannot be depended upon to continually preserve intact the electrical continuity of their rails over steam track crossings.

This point should, we believe, be just as carefully protected by law as the speed of trolley cars is now regulated in most cities by city ordinances.

The joint resistance in water mains, and the consequent damaging effect when current is passing upon the high potential side, is now pretty well known; engineers and others, who once favored the method of connecting water mains to the rail returns in a positive

district for the purpose of lessening the injury to pipes by electrolysis at such points, have now generally abandoned that plan, as it is found that more current is invited upon the pipes with resulting damage at or near the joints.

The effect upon water mains in the positive district is too well known to dwell upon, but one point may be referred to, and that is, while it is usually located in the vicinity of a power station, this is not an exclusive location. In a city recently examined we found four different points, widely separated from each other and from the power station, in negative districts, where the mains were positive to the rails, and the current was gnawing at the water mains silently and undisturbed, as the unseen worm gnaws at the roots of trees.

In view, therefore, of the apparent impossibility of preventing railway currents from straying, more or less, into the pipes, under the present single trolley system, resulting in their injury and destruction, we believe we are justified in requiring a method entirely insulated from the earth, before an actual remedy from electrolysis is found.

We are aware that it will entail more or less expense upon railway companies in making such a change, and we are also aware that they will derive a benefit in increased economy in operating, which should mean a corresponding increase in dividends; hence there should be no great opposition on the part of the railway companies to making such a change.

These are some of the incidents and impressions met with in making electrolytic investigations. If our exposition of the *cause and effect* of such incidents has thrown further light on the subject, or has proved of interest to you, we shall feel that the object of this paper has been attained.

DISCUSSION.

The President. We expected to have with us Mr. Woodbridge, of the General Electric Company, to discuss Mr. Knudson's paper, but he is not here, and I will call upon Mr. Brackett to open the discussion.

Mr. Dexter Brackett.* I did not come here at all prepared to say anything, Mr. President; I rather came to listen and to learn. It seems to me that, so far as our present knowledge of this subject goes, we are very well aware that the water pipes are suffering to a

*Engineer, Distribution Department, Metropolitan Water Works, Boston, Mass.

greater or less extent from electrolytic action, and I think what we all want to know now is the remedy. So far as I know, in no city have any very radical steps yet been taken to remedy the trouble. If there have been, that is one of the points I should like to have brought out here; and I should like to make the inquiry of Mr. Knudson. As I understand, the only remedy he suggests is a double trolley system.

Mr. Knudson. That is the only cure.

Mr. Brackett. I should like to inquire if there has been any case where a change has been made from a single to a double trolley system, for the purpose of remedying this difficulty?

Mr. Knudson. The only place I know of where this was the sole reason is in the District of Columbia, where a double overhead trolley has been put in. They were compelled, by Act of Congress, to make the change to a double overhead trolley. There are five Acts of Congress which call for that very thing; two amending franchises, and three granting new ones. Double trolley lines have been completely successful in their operation, both mechanically and financially, in Cincinnati for ten years.

Mr. Brackett. I was n't questioning whether they had been in operation, but as to whether any single trolley road had been changed to a double trolley, after being installed, for the purpose of remedying this difficulty?

Mr. Knudson. None that I know of, except the one I have mentioned.

Mr. Brackett. So far as our own system of works is concerned, I can only say that I have already found evidences of the electrolytic action, and some of them quite serious; and as all of the mains on the Metropolitan Works are of large size, the renewal of them would be a very expensive matter. One particular case, of which I have a few photographs here (Plate III, Figs. 1 and 2), is a main in Cambridge about 400 feet from a power station, where the output is in the vicinity of 6 500 ampères. It is a 48-inch pipe, laid about four years ago, but the main was not connected through until 1897, and was put in use in December, 1898. We have recently made an excavation to examine the condition of the pipe at a point where it passes under the street railway tracks, and where the bell of the 48-inch pipe is only $14\frac{1}{2}$ inches from the bottom of the rail. The pipe was brought near the surface at that point in order to avoid a sewer. The soil was moist gravel. We there found a difference of potential

Fig. 1. — Effects of Electrolytic Action on 48-inch Main Pipe, Metropolitan Water Works, near Cambridge Power Station.

Fig. 2. — Effects of Electrolytic Action on 48-inch Main Pipe, Metropolitan Water Works, near Cambridge Power Station.

between the pipe and the rail of between five and seven volts, the pipe being positive; and there were places where, in removing the earth which was encrusted on the outside of the pipe, pieces of the iron pipe from one eighth to a quarter of an inch in depth came off with the earth, and the pipe was then easily cut with a knife to the depth of from one fourth to three eighths of an inch. This has all happened since 1896 or 1897. We have had many evidences of the presence of the electric current on our mains, and have made numerous measurements to determine the strength of the current, but thus far nothing has been done to remedy the trouble, except that the railway company has in a number of instances increased their return wires and lowered the return current potential.

The President. There is one point I would like to ask Mr. Knudson about, and that is whether he knows of any case where a suit has been brought against the railway company to recover for damages done to the water pipes in which there has been any decision rendered, and if so, whether it has been in favor of the railway company or of the corporation or city bringing the suit?

Mr. Knudson. There are several cases under way, Mr. President, but so far as I know, there has been no actual decision in any case as yet. There is a case soon to be called, that of Dayton, Ohio, where a suit for damages has been brought against the railway company for something like $80 000. The Peoria case is still on. It will take some time yet to bring these suits to a head and get a decision, but I presume it will not be very long before there will be a decision in some one of the cases which are now pending.

Mr. Theodore H. McKenzie.* May I ask just one question? Suppose, for instance, that the rails are properly bonded, that the road is built under approved specifications, with a double bond at every joint on each line of rails, that the hole in the rail is properly brightened to secure good contact and the bond wire of suitable size, and that a proper supplemental bond wire is carried under the railroad crossings, similar to the one you spoke of at Reading, if that would not be ample to carry the current so that there would be no danger of the current leaving the rails and following the water pipes?

Mr. Knudson. That would carry the larger portion of the current without a doubt, but still there would be some leakage into the water mains. It seems to be impossible to completely confine the current to one path when there are two paths open for it; it is bound to stray

* Civil Engineer, Southington, Conn.

more or less. Then again, these very nicely bonded rails are all right at the start, but they are subject to corrosive action in the ground, where they come in contact with the moist earth, and sometimes to breakage, as at railroad crossings, where cars are passing in two directions, at right angles to each other, and at such places probably there is more danger of the bonds being broken than on the other portions of the road. You cannot keep a conductor of that class always in perfect condition, always a perfect conductor, the same as you might with an overhead wire. Where the track return is broken up by several hundred joints to the mile you cannot depend upon its always remaining a good conductor. Some of the bonds are sure to fail sooner or later.

Mr. McKenzie. With a supplemental wire carried in the center of the track, would n't that be sufficient?

Mr. Knudson. Supplementary wires have very often been found to be badly eaten by the action of the current escaping from the wire to the earth. I have seen cases where there was nothing left when the earth was removed but a streak of verdigris, and in other cases it was thinned down to about the size of a knitting needle.

Mr. McKenzie. Was that because the supplemental wire was not of ample capacity?

Mr. Knudson. No; because it was subject to the action of the current leaving the wire and going into the earth, and where it leaves it takes away the metal, whether it is copper or iron or lead, or whatever it is. Under such conditions, while they may be all right to start with, it is a very difficult matter to keep them in good condition.

The President. I would like to call on Mr. Lunt, of Lewiston, Me., who I understand has had some trouble with electrolysis.

Mr. Cyrus M. Lunt.* I am not prepared, Mr. President, to make any statement here which I think would be of value, but I have brought some specimens, which I would like to show, of services which I have taken up during the past year. Every one of them has shown a leak under the rails.

The President. Is there any other member present who wishes to ask Mr. Knudson any question?

Mr. John C. Whitney.† I would like to ask as to the comparative expense of this double return system and the single trolley systems which are now in use?

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* Superintendent of Water Works, Lewiston, Me.
† Water Commissioner, Newton, Mass.

Mr. Knudson. That depends almost entirely on the conditions of the railway, whether it has a fairly level road, or whether there are a number of grades to be encountered, and the length of the suburban lines, and all that sort of thing. It might vary all the way from perhaps $600 a mile up to $1 500 a mile, depending on distance and grades. In some places which I have visited, take Pawtucket, for instance, or even Providence, on some of the outlying streets there is nothing at all but the single trolley wire, they depending solely on the trolley wire for the main and upon the rails for the return. There are neither feeders for the trolley wire nor feeders for the track. In a case of that kind, if the positive or trolley wire is of proper size, it would mean principally putting up another wire of the same capacity, and that should not be very expensive. Of course there would have to be two trolley poles on each car; but I think if the railway company would adopt a system of that kind, they would find it very much to their advantage in the saving of power, because there is so much resistance in the rails and in the earth return that the company would in the end be the gainer.

Mr. McKenzie. Won't you tell us in a general way to what you refer when you speak of the double trolley system? Do you mean another wire overhead?

Mr. Knudson. Yes, sir.

Mr. McKenzie. And not another return on the track?

Mr. Knudson. No, sir.

Mr. McKenzie. That was tried in Meriden, — one of the first systems which was tried there, — and it was given up as cumbersome in operation.

Mr. George E. Winslow.* I should like to ask if you think, with the present system of a single overhead wire, with rails bonded as you speak of and return wire, the rails could be made large enough or heavy enough, or the return wire could be made large enough or heavy enough so that the two in combination could take all of the current that is put out without its being carried back, in part, by the water mains?

Mr. Knudson. It might take a large portion of it, but not all. There would always be some escape. We have made tests in cities where they have heavy girder rails, ninety pounds to the yard, well connected and well bonded, but there was no place where we did not find some difference of potential between the rails and mains.

* Waltham, Mass.

Sometimes it would run up to a volt, generally it stood under one volt. When the rails are in such good connection and the road is so well built as that, the readings generally are under one volt; but that is sufficient to cause damage to the water mains, if it is given time enough.

Mr. Charles K. Walker.* Mr. President, I should like to know what we are going to do about it?

I thought when I got through with cement pipe I was n't going to have any more trouble, but things grow worse and worse, and it seems that this iron pipe is worse than the cement pipe ever was. I never saw any worse-looking specimens of cement pipe than I have seen here to-day of iron pipe, and I would like to know what we are going to do about it. Is there any way in which we can fix it, or have we got to stand it? Suppose you go to an electric railway company and tell them they are damaging your pipe, and you would like some recompense for it, what would they say? Why, the chances are they would say they have just as much right under their charter as you have under yours, and you must take care of your own pipe. And I do not see any way out of it for us superintendents except to grin and bear it, and when a pipe gives out put in another pipe, the same as we did with the cement pipe. But that is not a very good thing to contemplate; I do not like to have that in prospect. I came down here to get some information as to how I could find relief, for things seem to be growing worse, and the pipes are growing worse; but if nobody can tell me what to do, I shall have to go home and tell my folks there is no hope for us, that we are goners. I have found, lately, trouble in the service pipes like what the gentleman from Lewiston has shown us; it has begun there, and where is it going to end?

Well, I do not know as it makes much difference to me. I am an old fellow, and you young fellows have got to stand it, I guess.

Mr. John C. Chase.† I would like to ask Mr. Knudson if it is practicable to tell whether a pipe system is in any danger before there is any direct manifestation of the effects of the current, or, in other words, if the electrical expert can step in and tell us that it is time for us to be getting after the electric railway company to bond their rails or provide a proper return for their current, because our pipes will begin to show signs of disintegration ere long. This is an in-

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* Superintendent of Water Works, Manchester, N. H.

† Civil Engineer, Derry, N. H.

teresting question in the case of a small water-works system with an electric railway in close proximity to a portion of its mains. Most of you, I presume, are familiar with such cases.

There has been no reason to apprehend any difficulty, but yet, according to what the gentleman has told us this afternoon, unless there is a proper return provided for the current, disintegration is going to take place, or is taking place already, and it is only a question of time — we do not know how long — before the whole system will be destroyed. Now, what I would like to know, to repeat, is whether the scientist can tell us the certain relation between the amount of work which is being done by the electric railway system and the pipe system that must not be exceeded, or can say positively when it will become necessary for the company to provide some method of return for the current, in order to save the pipes, before the story is told by the pipes themselves.

Mr. Knudson. That is a little difficult question to answer, as there is so much in it. In order to ascertain, first, what damage is going on, an electrical survey is generally made, and from that survey we can understand something about what and where the damage is. For instance, if we find in the positive district that the readings are fairly high, it is a pretty sure sign that the pipes are seriously damaged already. In such cases we have excavations made, uncover the pipes, make a personal examination, and in that way find the acute points of rapid electrolytic damage.

Now, in regard to making the railway companies pay. In some cases it works all right, and in others it does not. The railway companies generally do not seem to be inclined to admit that the pipes are damaged by their railway currents if there is any possible way out of it. In one case I had a talk with the president of a railway company, who is an electrician; he was standing on the edge of an excavation, and I was down in the hole scraping the graphite out of two or three soft places; I held up some in my hand and showed it to him, and said: "That is what you are doing to these pipes; you can understand that, as you are an electrician." Well, he could n't very well get away from that kind of evidence; that was too plain. Still, they do not like to admit that pipes are being destroyed by electrolysis. They sometimes admit that pipes have been damaged by their currents, and pay the bills, but it is not always done.

Mr. McKenzie. May I ask just one more question? Is it to be

expected that this damage by electrolysis will occur throughout the entire system? Is n't it confined practically entirely to a point near the power house, where the current leaves the pipes for the power house, or at such railroad crossings as you have described, or is it general throughout the entire system, or anywhere except where the track runs over the pipes?

MR. KNUDSON. It is both. Generally we find the acute positive condition near the power station; that is, where the current coming back on the pipe lines goes back to the rails. That is where the pipes are positive and where electrolytic action is most pronounced. But, as I said in the paper, very often we find these positive districts in negative sections of a city. There was one place I mentioned where there were four different localities widely apart and some distance away from the power station. I found that in one case there were new rails laid on a street, and at the terminus they had left about two squares of old rails in. Without a doubt those old rails were not bonded. We found there a difference of potential of 42 volts, the highest readings I have found anywhere. Just where the new rails left off and the old ones commenced there was a high positive reading, the current going back to the new rails. That is an instance of positive readings in a negative district. Then there are cases where the bonds have been broken on railway crossings, and anywhere where there is an opening in the rail return, it is very apt to cause a positive reading in that location, where the current after leaving the rails at such breaks will go back to the rails again somewhere in that vicinity on the other side of the break.

MR. MCKENZIE. Will the current return to the rails or to the supplemental wire immediately beyond the break, or will it follow the entire distance to the power station?

MR. KNUDSON. Some of it does return to the rails. It will go both ways. A good deal of it will come out at the nearest point where it can get a good connection to the rail return; but a portion of it will go on the main, following it down to the power station.

A MEMBER. Is it fair to suppose that all pipes in streets where there are railway tracks are being affected as distinct from pipes laid entirely outside of streets where there are no railway tracks?

MR. KNUDSON. Yes, sir; it is quite fair to suppose that, more or less, according to how well the rails are bonded, and how well the track returns are equipped with feeders. Of course, if they have proper overhead wires connected with the rails, that helps the rails

out. But in most cases on suburban lines they don't have any track feeders, but they depend on the rails entirely; and those are the places where we get the highest potential in the negative districts.

MR. FREDERIC P. STEARNS.* As I understand it, Mr. President, Mr. Knudson has told us very distinctly that a complete remedy for this trouble is a double trolley, with two overhead wires, or with insulated underground wires. Many of us may think it is impossible to obtain this complete remedy soon. It is a good thing to aim at, perhaps we will get it before long; but there is a difficulty which demands attention at the present time. Can Mr. Knudson tell us how much we would gain if we could have twice the capacity in the wires and rails that convey the electricity back to the power station; or, in other words, is there any definite relation between the damage that is done by six volts and the damage that is done by two volts, or between six ampères and two ampères, — whether by reducing the pressure or the quantity we can get a degree of safety from the action of electrolysis that will add many years to the life of the pipes?

MR. KNUDSON. I see what you mean, I think, sir, — simply adding more copper to the return. Of course, as I think I have said in the paper, that modifies the escape very largely. The acute places in a city, where there are high differences of potential, will be comparatively few in a case of that kind, and if such a system could be kept continually in perfect shape, it would be a great relief to the water mains. There would then be slower action, resulting in a longer life to the pipe, which might be extended over years instead of months; but I think it is practically impossible to keep up a perfect track return.

MR. G. H. SNELL.† I would like to inquire of Mr. Knudson whether a pipe which has a track running directly over it is much more liable to damage than it would be if the track was on the opposite side of the street?

MR. KNUDSON. Yes, sir, it is. I recall just now a similar case to that. We found in Providence, R. I., on Smith Street, a railway line running over a 24-inch main, from one reservoir to another, for a distance of about two miles, and on that main I found quite a heavy flow of current. The street was quite broad, and there was no reason, that I could see, why the rails could not just as well have been put on the opposite side of the street, and in that way give

*Chief Engineer, Metropolitan Water Works, Boston, Mass.
†Superintendent of Water Works, Attleboro, Mass.

some relief; that is, there would not be so much flow of current to the water main, on account of its not being so close to it. It is not a good plan, if it can be avoided, to allow rails to be placed over a water main.

Mr. Snell. I asked that question because in the town of Attleboro, where I come from, this last summer the selectmen granted a franchise for a street railway track directly over our force main from the pumping station, running about one mile. The pipe is about in the center of the track, and it seemed as though the track should have been put on the other side of the street, and the water department used every influence possible to have it so located; and yet the selectmen permitted it to be laid over the pipe, thereby not only making it more liable to be damaged, but making it very much more difficult and expensive to make repairs.

Mr. T. C. Gleason.* I would like to ask a question. In a town twelve miles below my town is an electric railway power plant, and the cars run into my town over about a mile of track. Now, would that be likely to affect our whole system?

Mr. Knudson. That is a little difficult to answer without having further data and looking the matter up. Undoubtedly your system would be in what is called a negative district, if the power station is twelve miles away, but some of your pipes may be used as auxiliary return for the track circuit, and some of the current will no doubt go by that route.

Mr. Gleason. What I wanted to know was whether it would affect only the pipes near which the rails go, or whether it would affect them all over our system?

Mr. Knudson. It might affect them anywhere on the system.

Mr. Gleason. Just the same as if the road really ran over the whole system?

Mr. Knudson. Yes, sir; depending, however, on local conditions.

Mr. Robert J. Thomas.† I have been told that the city of Lowell, which I represent, has been especially fortunate in not having any trouble to speak of from electrolysis. The first road was equipped with electricity in 1889, and we have found up to this time comparatively little trouble on account of electrolysis. In talking with the general manager of the road on several occasions, he has told me that the reason of it is the perfect or almost perfect bonding of the

* Superintendent of Water Works, Ware, Mass.
† Superintendent of Water Works, Lowell, Mass.

rails, and also the connecting of a return wire with the rails in various places along the line. Up to within two years ago we did n't have a single instance of trouble that I know of. Since then we have had a few cases where service pipes have corroded, which I could only account for as due to electrolysis. In every instance of that kind we have found that the pipe was eaten away under a conduit which was laid by the New England Telephone Company.

Mr. Knudson. Was the telephone conduit an iron conduit?

Mr. Thomas. No. It is made of some kind of earthen pipe, I think, and it is covered with a coating of cement. We had the soil tested there, and the greatest potential that was found was about one volt; and it occurred to me whether the fact that there was such a small pressure, such a small voltage there, would not account for the service pipes being attacked instead of the main, — in every instance where we have had any trouble with service pipe we have also uncovered the main pipe and have found that practically as good as when it was laid, not the slightest effect from electrolysis noticeable on it, — and whether the return wires and rails allowing such a little current to go to waste as is represented by about one volt, would not exempt the main pipe from being attacked; and whether in such a case as that we would only have to look at the service pipe for damage; in other words, whether the amount of voltage has anything to do with the size of the pipe attacked.

Mr. Knudson. If the track returns are in such good order, it would spread the trouble over a longer period of time. Undoubtedly it would show on the service pipes first, because as a rule the service pipes are nearer the rails and frequently made of lead. The telephone conduit, not being of metal, I do not think cuts any figure in the case. But if the soil is favorable, a low voltage, even as low as .001 of a volt, is liable to cause electrolytic action and damage the pipes. Sometimes, if the soil is sandy and fairly dry, we don't find it; the current is coming out somewhere else. It must come out somewhere; whenever it goes in, it must come out again on some portion of the system. It is difficult to tell how much damage is being done on the main pipes because we don't know how much current is flowing through them. There may be considerable current flowing through, and it would n't show itself except at the joints. If a little current was flowing through, you would find it, perhaps, in the course of time in the shape of pittings on the positive side of the joints, that is, on the side that is farthest away from the power station, whether

the spigot side or the bell side. We have found it so in a number of cases. Of course we can seldom see the inside because the pipe is in service, but on the outside we very often find pittings. If it is on the bell end it is often at the edge of the bell, as was shown by the picture on the screen, and if it is on the spigot side it is quite near the bell joint. With that low potential your trouble would be extended further into the future, that is, if they keep up these conditions. We don't know what acute points there are, perhaps, in the outlying districts, or at a distance from the power station; there may be damage going on there which no one knows anything about. It was quite a revelation when on my examination in Reading I found these different places. It was a surprise to the railway people as well as to the water-works people to see what damage was going on at places which they had no idea of; for example, at the railroad crossing. That is a point which is extremely important, I think, because it showed not only danger to human life, but a ruined water main was actually found there.

Mr. Thomas. I will say that in these cases to which I have referred, I reported to the railway people, and they immediately put a test car right over the line to find out if there was any leakage; and they were very anxious to prevent it in case there was, because, as they said, they did n't want to lose any power by having their current go to waste, so they were just as anxious to have any leakage from their system stopped, apparently, as we were.

Mr. Knudson. I find it is often the case that fair-minded railway people are just as anxious to have any leak in their system discovered and stopped as the water-works people are. In some cases during a survey, I have been requested by railway officials, in case any bad spots or leaks were developed, to report them, together with suggestions for improving same, and they would correct them as soon as possible. The trouble is, however, that while such special leaks may be improved upon by rebonding the rail joints, it is not, generally speaking, an effective remedy for electrolysis, for the reason that, improving special leaks, while most important at the time, is no guarantee for the future so long as the rails are used as a return, and that is the point we are trying to make. It is not only the present, but the future safety of water mains which should be considered in looking for an effective remedy from electrolysis.

Mr. Freeman C. Coffin.* If I understand the speaker, there

* Civil Engineer, Boston, Mass.

will be a saving to the companies by the construction of a double return wire in the saving of power. I should like to ask him if he states that as a general principle, or if a mathematician can show that in figures; if it is able to be shown in figures to the companies in a way that will be convincing, as an offset against the fixed charges or cost of operation.

Mr. Knudson. I do not know of any recent change from a single trolley to a double trolley, except in the District of Columbia; but I have seen estimates that have been made by competent railway contractors. Some of them claim that a saving can be made in power of something like twenty to twenty-five per cent. by having a proper insulated metallic return, instead of depending on the rails as a return, and having the current stray off into the water pipes, and being obliged to overcome the resistance of the rails and the earth. There is no doubt that it would be an advantage to the railway companies if they would more generally adopt the insulated return.

Mr. Fred. Brooks.* I have been told that while it might be expensive for an existing railway to change its system, it would not be particularly expensive in laying out new work to arrange the system so as to avoid these destructive consequences; that one safe method would be to use the three-wire system. Whether that means what has been termed here a return wire or something else, I should like to learn. Another statement which I did not understand was that the electrolytic effect could be greatly reduced by working a line in sections by some system in which there is a crossing over of the current in different parts of the line with changing over the trolleys; I should be glad to have that explained.

Mr. Knudson. The three-wire system has not been put into use anywhere, so far as I know. There are serious objections to it because it necessitates a balancing of both sides. You must have as much load on one side as on the other, and that is practically impossible in railway traffic. In speaking of a return wire I refer to a double overhead trolley or a double underground trolley, both conductors insulated from the earth, and from each other of course, making a complete insulated metallic return.

Mr. George A. Stacy.† I had a little experience, fortunately on a Sunday evening, which I will relate. We had a leak in a service pipe, and on taking it out I decided from what I saw that it showed

*Civil Engineer, Boston, Mass.

†Superintendent of Water Works, Marlboro, Mass

the effect of electrolytic action. This pipe lay at right angles to the street railway line. The original rails of our street railway were very light, designed for a horse-car track, and they changed to electricity as a motive power, being one of the first electric roads installed in the State. Some of the old rails were replaced with heavy girder rails, but the light rails remained on this particular section for a long while. At one point, beyond where this service pipe to which I am referring crossed the track and the power station, there was a switch which was in pretty bad condition. I know that two winters ago they did n't have to put any salt on it to keep it thawed out; it was boiling some of the time, and they let it go, for at that time the company was n't very wealthy. Well, I thought I was safe, for at the power station at that time, very near the dynamos, was a four-inch fire supply pipe for their sprinklers, and I came to the conclusion that if there was any trouble it would follow along and show itself at the terminal on that pipe; and the people in the power house would get it first, and know how good it was; and I felt as if I did n't care how long it would take me to get down there and shut the water off.

But this thing occurring nearly half a mile away from the power station, and it having all the ear-marks of electrolytic action that I have read or heard of, it struck me that while I thought I knew something about it before, I really did n't know anything, by its showing evidences of its effect on this pipe, when it had a good lead clear down to the station. This was a cement-lined service pipe, and the lead connection shows evidence of pitting all over it, and it has scales on it which look very much like those on a piece of iron that has been heated very hot and taken out and cooled, although the scales are granular; that is, you take it and scratch it with a knife or with your thumb nail and it crumbles all up. And what I would like to know is whether or not these facts, under such conditions as I have described, would warrant a man in thinking that this trouble was caused by the electric current at that point. The main pipe is located close to the track on the outside, say within two feet of the rail; the service pipe crosses under the track into a building; and if this has happened in one case, are not all the service pipes on that side the whole length of the street likely to be in the same condition? And if they are, is it worth while to go to bed at all this winter? As I understand the subject presented here by this very able and interesting paper, it is only a matter of time when this electrolytic action is going to destroy

the pipes unless there is a change in the system to keep the current out of the ground; and if this is not done, the only thing we can do is to try to get the railway companies to fix their rails up, so as to make the current in the ground as light as possible, so the pipes will last at least as long as we live, or until we go out of the business, and then some other fellow can have the trouble.

The President. I would like to ask Mr. Knudson if I understood from him that he had some form of ordinance he suggested to the city of Providence and to the city of Pawtucket in regard to the granting of franchises to electric railway companies, and that he advised them to adopt? If he has such a thing, I have no doubt it would be of interest to some members of the Association.

Mr. Knudson. It was not in regard to the cities of Providence and Pawtucket, but I made the remark, I think, that I had a copy of an Act of Congress which covered the construction of electric railway lines in the District of Columbia; and if you would like to hear it — it is very short — I will read it. Under section three it is provided that "the motive power shall be electricity, and if the trolley system is used a return wire of equal capacity to the feed wire and similarly insulated must be provided, and each car shall be equipped with a double trolley. No portion of the electrical circuit shall under any circumstances be allowed to pass through the earth, and neither pole of any dynamo furnishing power to the line shall be grounded." That is very short, and I think it is to the point.

The President. I would like to call on Mr. Connet.

Mr. F. N. Connet.* I wish to remark that in these days when there is so much literature with reference to 8 000 volts and 10 000 volts, it seems almost as if two volts was too small to consider. But I believe that at Niagara Falls, where they are depositing by electricity several tons of copper and aluminum every day, the voltage is but two volts. That is the first thing I wished to say.

The second point is this: I think there is considerable danger that, with non-experts, plain corrosion will be mistaken for electrolytic action. I recall some photographs that I saw some years ago of rails that were taken up from a tunnel on the Lehigh Valley Road in the western part of New Jersey. These rails when laid were about sixty pounds to the yard, and they had been corroded in a very few years till the weight was only about thirty pounds per yard. Now if that had happened to-day everybody would have said it was due to

* Engineer, Builders Iron Foundry, Providence, R. I.

electrolytic action, but I think there was no electricity within twenty-five miles of that tunnel. In that case it was due to the absorption by the moisture of the sulphur from the locomotive gases and the formation of a sort of weak acid solution. The photograph of those rails looked exactly like the photographs that Mr. Knudson has shown us this afternoon. I suppose that an expert can determine the difference between corrosion and electrolytic action, but I think there is great danger that some of the rest of us might mistake the one for the other.

Then there is a third point, and that is, the method suggested for getting around the difficulty. Now, I have a method which I think will get around the difficulty, and I think, perhaps, it will be adopted before the double trolley system is adopted. That method is for the railway company to swallow up the water company, and then we will not hear much more about the trouble from electrolytic action.

Mr. Knudson. The deposit of copper or other metals in large amounts at only two volts pressure merely means a low resistance between the electrodes, such as always exists in an electrolytic bath of this kind. Now, we find that very thing, only on a different scale, in railway electrolytic investigations. For instance, in soil where it is very wet, or perhaps where there are alkalis or acids that lower the resistance, a larger amount of current would flow, and the pipe consequently be very soon ruined; while in other cases, even at higher voltages, which may run up to twenty or thirty volts, if the pipe is in a sandy soil or a fairly dry soil, the action may not be at that point, but at some other place where the earth is a better conductor. Sometimes if the soil is impregnated with salty material, or a small percentage of ammonia is present, the action is more rapid. Unusual deposits in the soil, such as are discharged from factories or are present in garbage heaps, or such as might be caused by locomotive gases in the tunnel mentioned by Mr. Connet, sometimes produce chemical action and results similar to that of the electric current; these conditions are rare. Such action and results never occur in ordinary soil unless caused by electric current, and ordinary corrosion need never be mistaken for them.

Mr. Connet. The only point I meant to bring out was that under certain conditions we ought to be thoroughly frightened at two volts, even though it looks like a very small amount, because that is in itself sufficient to do a great deal of damage.

Mr. Knudson. It certainly is, particularly if the soil conditions

are favorable, and they usually are favorable in many places in a city.

Mr. Brackett. If there is no further discussion of Mr. Knudson's paper, I wish to say that I think the discussion this afternoon has certainly shown that this is a subject in which the Association is very much interested; and I wish to move now that a vote of thanks be given to Mr. Knudson for his very interesting and instructive paper.

The motion was adopted by a rising vote.

LANDSCAPE PROBLEMS IN THE IMPROVEMENT OF SPOT POND RESERVOIR, METROPOLITAN WATER WORKS.

BY FREDERICK LAW OLMSTED, JR., LANDSCAPE ARCHITECT, BROOKLINE, MASS.

[*Read September 20, 1900.*]

Mr. President and Gentlemen of the New England Water Works Association, — It is a privilege that I value and an honor which I think somewhat unusual that a member of another profession should be called upon to address a body of technical men on their own subject. It is rather a dangerous privilege, too, for I may be put in the attitude of assuming to instruct able water-works engineers and experienced superintendents how to do their own business.

If anything I say to-night should seem to indicate such an attitude, I assure you in advance that it is quite unintentional. I no more think of assuming to be a water-works engineer or a professional reservoir builder than I think of pretending to be a painter of landscapes, though both professions touch at points upon my own.

Almost every constructive work is planned, not absolutely and completely by the mind of one man, but by coöperation, usually by the coöperation of many minds. There may be, indeed there generally is, one controlling designer, but his assistants do not merely carry out his orders like so many automata. The man has never been born who could know all there is to be known bearing on any subject, or who could think of all the ideas applicable to any one subject. For this reason those with and through whom any designer works help him to plan better as well as quicker. Barring exceptional strokes of genius, all the best constructive work is planned in this coöperative way; and wherever constructive work becomes complicated in character, or involves the consideration of more than one point of view, it is almost essential that there be conference between men of different training. Even if one point of view be clearly supreme, a master of that aspect of the case will be helped by the ideas of those who can see the problem from another side.

In the matter of reservoirs, I speak, then, as one who would help by contributing knowledge of a special subject incidental to the main purpose for which they are ordinarily built.

In the case of Spot Pond Reservoir, which was created in the midst of lands set apart for park purposes, the question of appearance had, it is true, unusual weight, and it is partly because the problem of constructing a reservoir in a park has come up elsewhere and is likely to come up again that I am especially glad, as a park-maker, to address you as reservoir makers; but there is another aspect of the case that I cannot refrain from touching upon here. It does not often happen that the site chosen for a park proves to be needed for a reservoir, but every reservoir from the mere fact that it is an open sheet of water has a strong element of beauty, and it has always seemed to me that it would be possible for many a municipality to get much more return for its money spent upon reservoirs if that fact were recognized, and if a well-directed effort were made to render the potential beauty of these sheets of water positive and available.

A fire-engine house is a purely utilitarian structure, but it is well recognized that, so far from being ugly, it may be made one of the interesting and attractive buildings of a city without the expenditure of much more money than is required to meet the absolute material requirements. It is not a question merely of ornament or primarily of ornament, as too many engineers seem to think. The modification of proportions and slight changes in the form of necessary details are enough to change an ugly or commonplace building or bridge to one that is distinctly pleasing.

And so it is with reservoirs. I believe that none of the work done by the engineers who controlled the improvement of Spot Pond was unreasonable or fantastic from a strictly engineering point of view, in spite of the fact that they adopted many of the suggestions of a landscape architect; yet Spot Pond when completed will have a very different aspect from that of the typical distributing reservoir, and one more pleasantly harmonious with the surrounding landscape.

When the work of the Metropolitan Water Board began, there were in the rough upland of the Middlesex Fells several natural and artificial ponds utilized with their limited watersheds as sources of supply by the neighboring towns. The largest of these, Spot Pond, had been in view from the beginning of the Metropolitan project as

a suitable location for a northern distributing reservoir for the district, to supplement the very inadequate reserve at Chestnut Hill, which amounted in 1898 to only about two and one half days' supply for the whole district.

Spot Pond lies in an elevated rocky valley of irregular form which seems originally to have had its outlet to the southward, but which was so completely blocked by a dam of glacial deposits that the pond thus created found its overflow at a low point in one of the enclosing ridges, and has ever since run off to the eastward. (Fig. 1.) On account of its origin, the pond was naturally shallow toward the northern or up-valley end, and the original shallowness of this end has been greatly increased by the material carried in by the streams and by the accumulation of swamp vegetation working out from the margin. The rough tract of upland, known as the Middlesex Fells, in which the pond is situated, is about two miles square, and contains several other more or less interesting valleys, and countless crags, hills, and basins almost uncultivated and unoccupied, although quite surrounded by populous towns. Some of the other valleys had been artificially dammed for water-supply purposes, and the immediate shores of these reservoirs, as well as of Spot Pond, had thus come under water-board control.

On account of the exceedingly interesting scenery of the Fells and the fact that they were as yet wild and unoccupied while close to a large population, nearly all of the private lands of the region (amounting to eighteen hundred acres) were purchased in 1894 by the Metropolitan Park Commission, for the benefit of much the same district as that served by the Metropolitan Water Works, and the care and control of the lands held by the local water boards on the margins of the reservoirs were then turned over to the Park Commission. The chief conditions, then, which confronted the Metropolitan Water Board in 1899, when the method of utilizing Spot Pond as a distributing reservoir came up for definite decision, were these: —

Parts of the pond were shallow and mucky, with the result that a perceptibly disagreeable taste and odor were given to the water stored in it, thus making some radical treatment of these shallow and mucky portions imperative. (Plate I, Fig. 1.) The pond when up to its highest normal level (154 feet above Boston base) contained a supply of 758 000 000 gallons in its upper twelve feet, the portion below Elevation 142 being unavailable. This amount, added to that of the Chestnut Hill Reservoir, would raise the available

FIG. 1. — SPOT POND IN 1895, BEFORE ITS IMPROVEMENT.
Scale, 1700 feet to an inch. Contour interval, 5 feet.

supply within the district to only 11.7 times the daily consumption, and it was the opinion of the board's engineer, Mr. Stearns, in view of the steadily increasing daily consumption, that a much larger storage ought to be provided. Incidentally an increase in the height of the water was to be desired for the sake of the increased pressure in the distributing system. Furthermore, the fact that the pond was surrounded by a reservation of the Metropolitan Park System, and indeed was itself a most important landscape feature of that public domain, made the question of appearances of far more obvious importance than is usual in the case of reservoirs. Clearly, if the community had seen fit to spend nearly a million dollars for the sake of acquiring and preserving certain scenery, any radical changes in an important element of that scenery should not be made without a careful consideration of the landscape effect and a clear conviction that any damage to this valuable scenic asset was more than counterbalanced by other gains. (Plate I, Fig. 2.)

It was probably owing to this last consideration that my firm was called in to consult with the engineers, in order that we might help them by suggestion and advice as to the landscape effect of various methods of accomplishing their purposes. The quality of results from the strictly engineering point of view was the prime consideration, and no one could judge better of this than the gentlemen in question. The appearance of the results, however, though secondary, was of such importance as to determine the election of methods when engineering considerations did not preclude a choice.

It was while the plans were still in a formative condition that our suggestions were made. The preliminary plans were furnished to us by the engineers, and we then prepared detailed plans for the grading and such other details as we thought likely to affect the landscape. (Fig. 2.) If any particular of our plans tended, in the opinion of the engineers, to interfere with the excellence of the reservoir as a storage place, that particular was at once modified; but when some feature of the plan, as not infrequently happened, without affecting the engineering excellence of the reservoir, involved more expense than some other equally efficient arrangement, there was a discussion of merits. An estimate of the additional cost was made by the engineers, and if we then really thought the probable gain in appearance worth the difference in cost, we stated our opinion, backed by our reasons. We were cautious and conservative in urging such extra expenditures, and the engineers were most fair-minded

Fig. 1. — Shallow Flowage at Northern End of Pond, before Improvement.

Fig. 2. — Pickerel Rock, before Improvement of Pond; showing Foliage to be destroyed by raising Water Level.

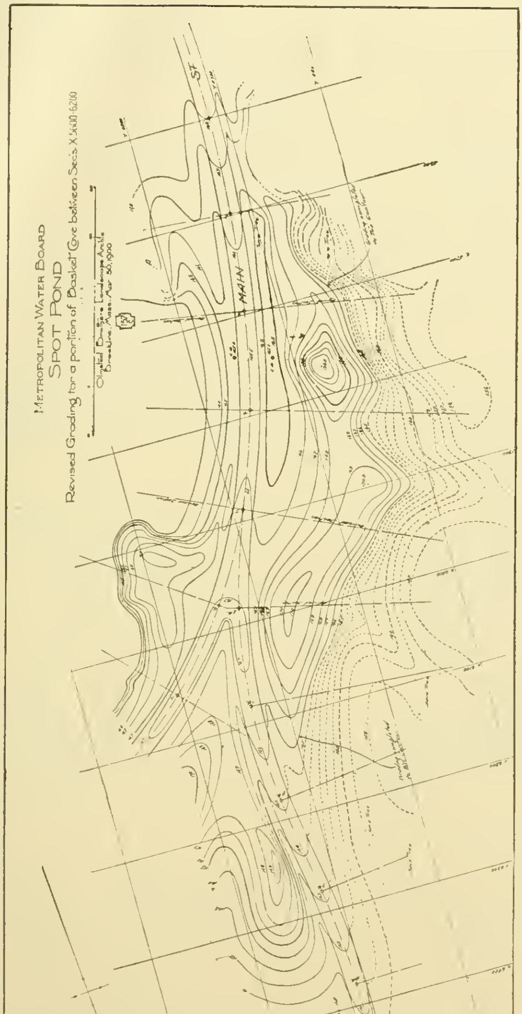


FIG. 2. — GRADING PLAN.
Scale, about 192 feet to an inch.

in their consideration of such cases, with the result that there were very few points strongly urged by us that they felt unable to accept.

Five alternative plans for improving the reservoir were seriously considered. (See Fig. 3.) They were: —

A. Leaving the water level unchanged, to excavate the muck and the loam-covered sand from the shallow portions of the pond so as to give a minimum depth of ten feet. Estimated to provide 1 006 000 000 gallons capacity.

B. Leaving the water level unchanged, to excavate as in Plan *A* except in the mucky western arm, and to fill that so as to exclude the water from it entirely. Estimated to provide 899 000 000 gallons capacity.

C. To dike off the mucky western arm, dike other low points on the margin of the pond, and raise the water six feet after excavating enough material from the bottom to give a minimum depth of fourteen feet. Estimated to provide 1 354 000 000 gallons capacity.

D. To raise the water level six feet as in Plan *C*, but to extend the excavation to the western arm. Estimated to provide 1 448 000-000 gallons capacity.

E. To excavate all the shallow portions of the pond as in Plan *D*, but to raise the water nine feet. Estimated to give 1 764 000 000 gallons capacity.

The landscape architects submitted a report on the comparative value of these schemes as judged by their effect upon the landscape, showing the immediate harm or gain from each, and what opportunity there was in each case for the future concealment or natural healing of the injury.

Roughly summarized, the report was as follows: —

Plan A would not injure the existing landscape, but on the contrary would improve its appearance by maintaining the pond constantly at its normal high-water level. The great amount of material excavated could be made into a hill at the northern end of the pond, and when clothed with vegetation would strengthen the frame of the pond where its shores were dangerously near to uncontrolled private property.

Plan B would preserve the beauty of most of the shore growth, but would render the west shore tame and uninteresting, and cut short the east and west views of the pond. If the road were shifted so as to pass to the east of Deer Hill and along the new shore

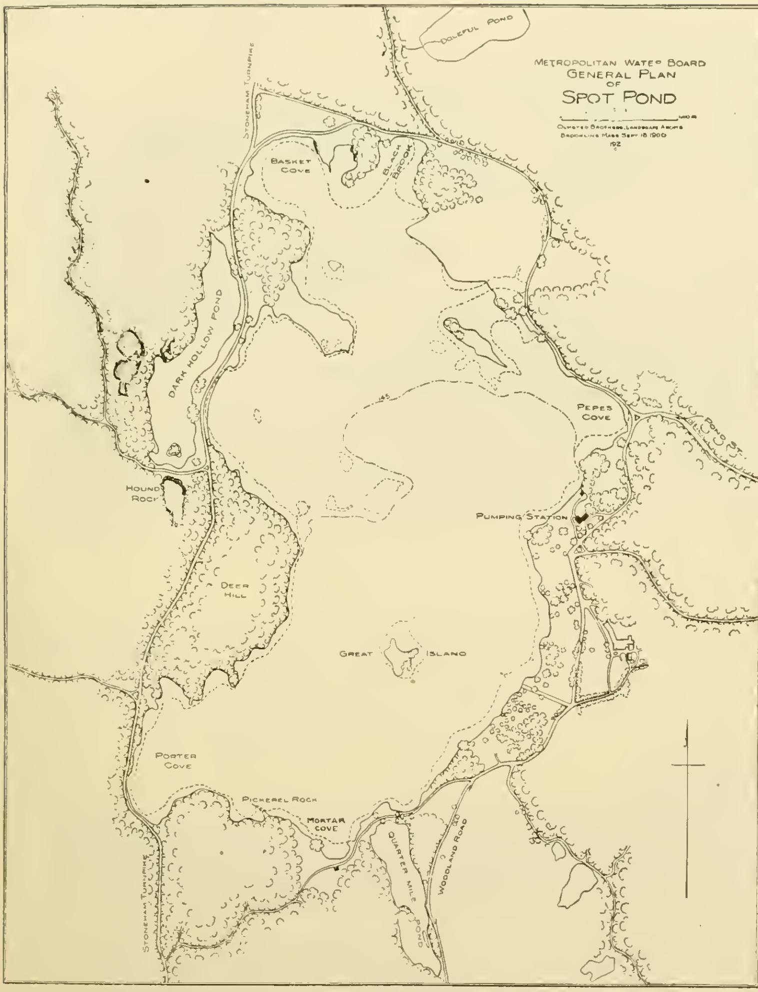


FIG. 3. — GENERAL PLAN OF SPOT POND, SHOWING OLD OUTLINE, AND OUTLINE AS FIXED BY PLAN E.

line, the loss of landscape effect would in time not be noticed, but would still be real and permanent.

Plan C had all the objectionable features of Plan *B*, increased by the need of a dike considerably above the level of the land behind it, and had also all the disadvantages of a change in water level.

Plans D and *E* differed only in the amount of the proposed raising, and a careful study showed that while the landscape would be seriously injured by raising the water even two or three feet, the amount of the damage would be little greater with nine feet than with six. The reason for this was that the best of the foliage framing the pond and overhanging its borders was borne upon the waterside trees, which had developed in the full sunlight offered by the open pond, whereas most of the trees further from the water, growing behind this vigorous margin, had lost their lower foliage and become tall and "stemmy." This condition was modified at various points about the pond, but on the whole, Plan *D* offered no considerable landscape advantages over Plan *E*, and was far less desirable from an engineering point of view.

Plan *E* was finally adopted. (See Fig. 3.) This gave the greatest storage capacity, and though temporarily destructive of much beauty, offered the possibility of making the finished work harmonious with its surroundings and not glaringly artificial.

The chief landscape problems coming up in carrying out this plan were briefly these: Tree cutting, shore treatment, form of dikes, disposition of surplus fill, relocation of roads, and planting.

The first tree cutting consisted of a wholesale removal of all trees standing lower than Elevation 163, the proposed water line. Then a second cutting was made, removing such trees as by their weakness or lack of lower branches injured the new forest edge. Meanwhile, a one-foot contour map was made at a scale of forty feet to the inch, showing the conformation of the ground both above and below the proposed water level. On this map individual trees were located at frequent intervals. Each tree so located was marked by a numbered tag and was designated by a corresponding number on the map, an arrangement of great value in studying upon the ground the exact and detailed relation of any proposed grading to the existing conditions of surface and vegetation without the expense of actual staking out. A somewhat minute regard for this relation is essential to agreeable landscape work, and in many cases it is impossible to perfect it without repeatedly "trying the plan on the ground," either by staking

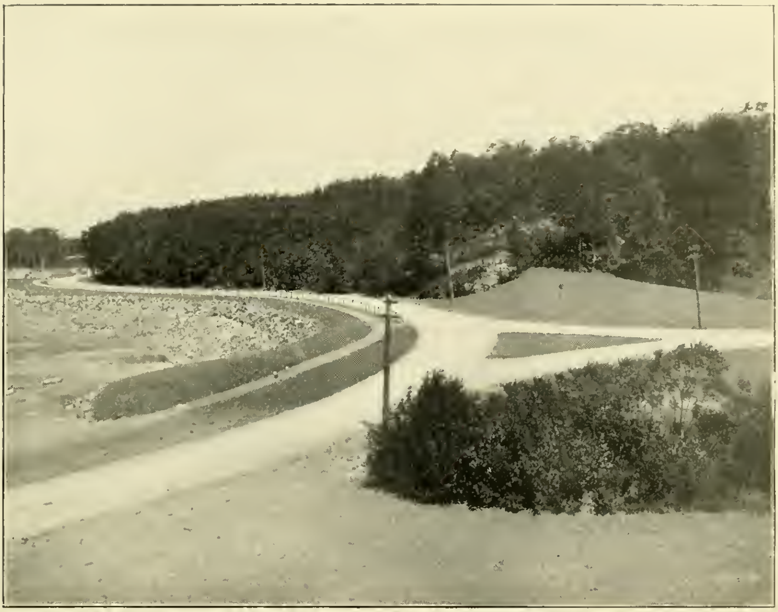


Fig. 1. — Pepe's Cove Dike, looking North along Crest.

Fig. 2. — Gravel Shore, Porter Cove.

out the finished grades or by using a sufficient number of accurate reference points, such as cross-section stakes or the more conspicuous numbered trees.

The shore treatment was an attempt to give to the new shores an appearance not conspicuously different from that the pond itself would have given them in ages of erosion. Rocky ledges were simply stripped of soil and allowed to rise from the water in whatever shape they happened to be. This is, perhaps, the most satisfactory kind of shore. It is perfectly clean, perfectly stable, and most natural in appearance. Where there was no outcrop, the shore was formed of bowlders, gravel and bowlders, gravel, or sand, as the surroundings suggested. Where a fairly steep slope came down to the water, as was the case along a large part of the shore, it would be natural for the water to wash away the finer material of the banks, leaving exposed, in course of time, a bowlder shore. Such shores were made around much of the pond. They differ from ordinary riprap in the intentional unevenness of their surface, and in the use, as far as practicable, of weathered surface stones. (See Plate II, Fig. 1.) Gravel with bowlders, or gravel alone, was used where the slopes were more gentle. (Plate II, Fig 2.) The bowlders were, as far as possible, sunk for about half their diameter into the gravel, as nothing can be more awkward and artificial in appearance than a sprinkling of bowlders set about on top of a finished surface.

Sand beaches forming broad shelves at the water level with a slope of about one in twenty were made on some concave stretches of shore. (Plate III, Figs. 1 and 2.) A sand beach, and in less degree a gravel beach, will not remain upon a point unless all the neighboring material is sand as well. It is carried away by the waves, and the underlying rocks, if there are any, are exposed. But on a nearly flat or concave shore no form of protection is more resistant or secure than a beach of sand when once its breadth and slope are adjusted to the wave conditions, while the constant agitation of the sand interferes with objectionable plant growth in the narrow band of shallow water.

Whatever shore treatment was used, all soil was stripped to the contour two feet above the proposed water level, and the shore treatment carried up to this line in order to prevent wave action from carrying into the pond any pollution from the banks.

The two ponds which were diked off from the main reservoir, Dark Hollow Pond and Quarter-Mile Pond, received no shore treat-

ment. The water in these ponds is not to be used, and they are so small that wave erosion will probably never strip the root protection from their banks.

The other elements of the landscape problem are so interdependent that perhaps the simplest way to deal with them is to take up in order the important localities around the pond, showing briefly what was done in each case, and what effect was aimed at.

At Pepe's Cove, as the map shows, Pond Street comes up hill to the water. This rise was exaggerated by the necessity of building a dike across the opening in the pond shore, and, unless remedied, would very forcibly and unpleasantly suggest the artificiality of the embankment. A spur of filling was run out from the hill to the north, and the road, on passing this, was divided by a triangle. (See Plate II, Fig. 1.) Both sides of Pond Street and the triangle are to be planted, and when the trees are grown it will be impossible to see the pond and the descending hill on Pond Street at the same time from the road. The spur of filling also strengthens the dike as seen from across the pond, disguises its artificiality, and ties it in with the adjacent hill.

To the north of Pepe's Cove, the shore along which Pond Street runs presented a stiff, artificial line of causeway. This was improved, on raising the pond, by shifting the road inshore, and filling in a slightly irregular way, both as to shore line and profile, between the road and the pond. This strip is to be planted at points where the ground rises and projects into the pond, but left open at other points where planting would interfere with the best view of Pepe's Cove.

The large low-lying field on the northeast side of the pond was occupied by a long dike to hold the water back from the swamp east of Pond Street. This dike was made very broad, sloping very gently from its greatest height near the pond and covering most of the meadow to a considerable depth with sand and other material excavated from the pond.

The next dike, at the valley of Black Brook, which connected Doleful Pond with Spot Pond, was formed like a series of small hills, thus disposing of surplus fill and minimizing the artificiality of its appearance. These elevations were so arranged that on going along the road toward the west, one would see first the pond and not the depressed meadows, and then the meadows and not the pond. (Plate IV, Fig. 1.) Farther on in the same direction the road forks, the right-hand branch being the old road, the left-hand running

FIG. 1.—SAND BEACH ON LEFT; REGRADING OF SHORE AT PEPE'S COVE.

FIG. 2.—LEDGE AT PEPE'S COVE; SAND BEACH TO RIGHT IN FOREGROUND.

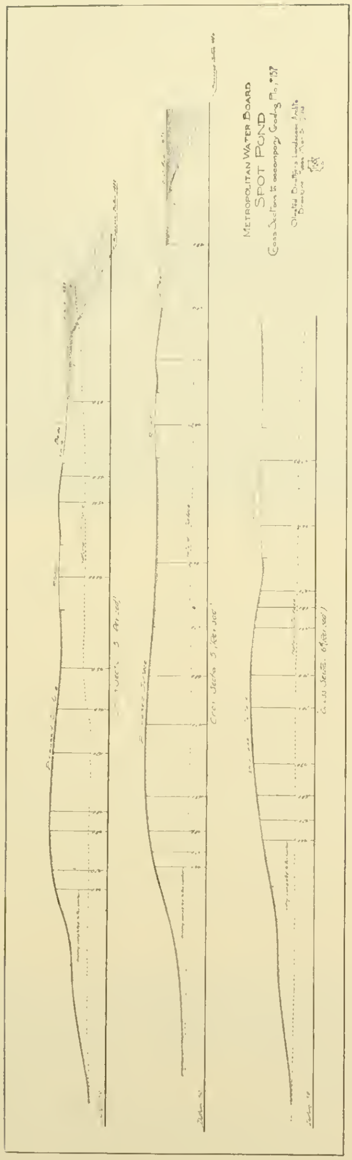


FIG. 4. — CROSS SECTIONS OF GRADING IN FIG. 2.
Scale, 60 feet to an inch.

over the fill north of Basket Cove. This long, broad, curving hill disposed of a great amount of surplus material, which was carefully modeled to harmonize with the existing topography. (Plate IV, Fig. 2.)

In the course of the work, changes from the estimated quantities of excavated material necessitated adjustments in the grading plans from time to time. A portion of one such revision is given in Fig. 2, where the broken contours show the lower portion of the fill, previously executed in accordance with the first plans, and the full contours indicate a method of completing the fill agreeably with less material than the original plan called for. Cross sections of this fill are shown in Fig. 4.

To the north of the shore road is a long mound to be planted with trees, as a screen to the private lands behind it, and the Stoneham Turnpike, running north and south along the west shore of the pond, is curved slightly where it is relocated upon the fill, to close the view of houses outside the reservation on the north and to fit the curve of the main driveway about the pond.

Opposite the western arm of the pond the Stoneham Turnpike ran over a causeway between the western arm of the pond and Dark Hollow Swamp. (See cross sections, Fig. 5.) It was thought that the extra capacity to be obtained by relocating the road along the west side of the swamp, clearing the swamp of peaty material, and joining it to the pond was not commensurate with the expense. The causeway was therefore raised and given greater breadth, an irregular outline and a slightly undulating profile, by means of the material excavated from the adjacent pond bottom. Such parts of the old surface as were high enough were saved, and the new surface adjusted to them. A sand beach was made on the side toward the pond. To avoid the unnatural look that land would have so much below the level of the pond and yet so close to it, to avoid the necessity of making the causeway impervious under the eight feet of head between the reservoir level and the swamp, and to secure an additional element of pond scenery, the swamp was flooded to the same level as the reservoir by means of a short, inconspicuous dam at a narrow point on the north, whence the overflow was carried by a ditch to Doleful Pond. Any one going south along the road sees first, on his right, a long view down Dark Hollow Pond, well terminated by Hound Rock. To his left the trees will block any view of Spot Pond. (See plan, Fig. 3.) When once down upon the level

FIG. 1. — TOP OF DIKE ACROSS BLACK BROOK VALLEY, LOOKING WEST.

FIG. 2. — FILL AND RELOCATED ROAD, NORTH OF BASKET COVE.

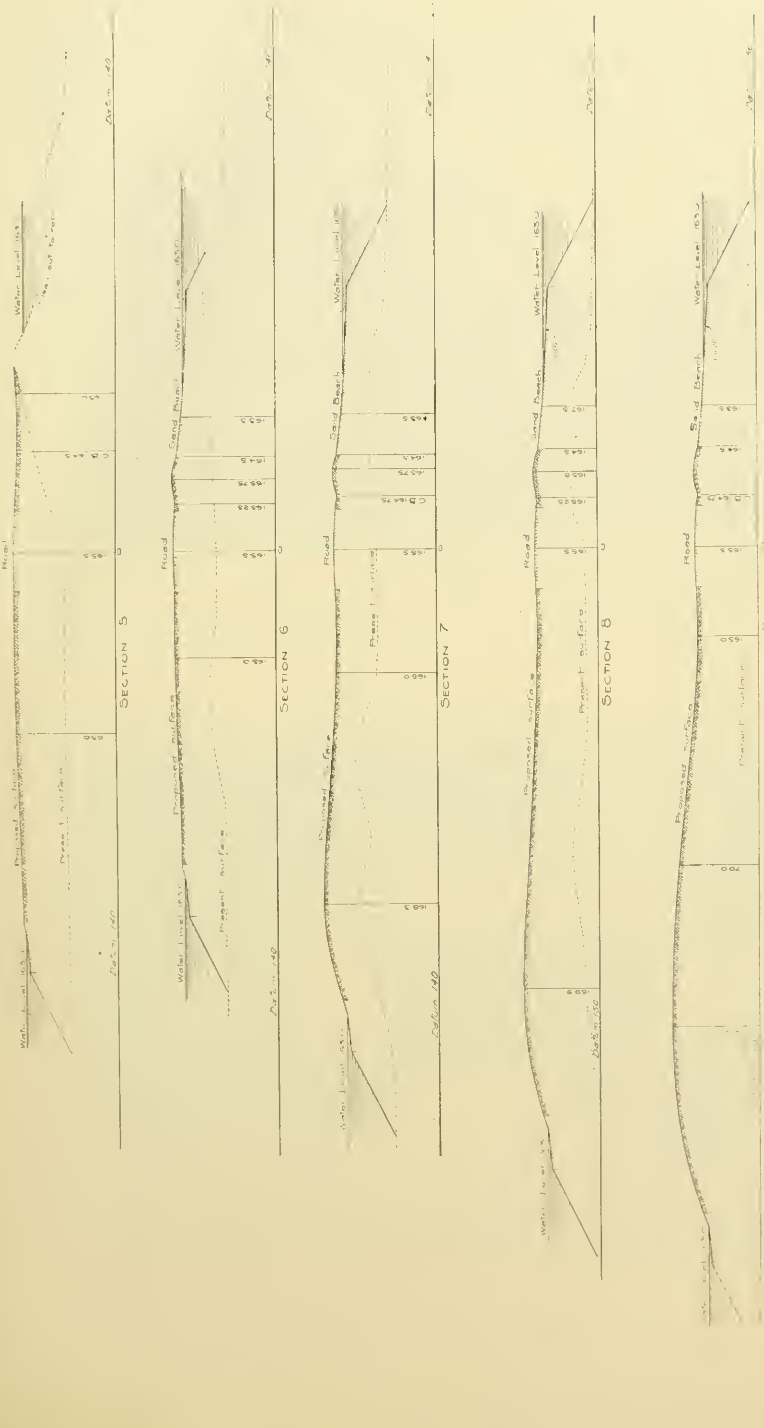


FIG. 5. — CROSS SECTIONS OF CAUSEWAY AT DARK HOLLOW POND.
Scale, 50 feet to an inch.

causeway, a fine diagonal view of Spot Pond, with Great Island, opens on the left, while on the right the trees will close in, preventing a distraction of attention between two points of interest. Still farther along the causeway, when Deer Hill begins to cut off the view of the pond, a nearer view of Hound Rock and the end of Dark Hollow Pond opens on the right, effectively framed with foliage.

At Mortar Cove, the extreme southern end of the pond, is a dike crossing the flat deposit of glacial *débris* which fills the valley. The southern gatehouse now stands on this dam. Several rounded hillocks, clothed with a good growth of oaks, rose above the necessary level of the dike. (See Plate V, Figs. 1 and 2.) There was no great surplus of fill to be had here owing to the deep water of the pond and the clean gravel bottom which did not need to be excavated. It was thus impracticable to conceal the valley below the pond level by any large amount of extra grading. The back of the fill is, therefore, to be planted thickly with trees, which will in time cut off any view from the road of the low ground to the south. (Plate VI, Fig. 1.) The surface is modeled to fit the projecting hillocks, saving as many trees as possible.

The swamp to the east of the southern gatehouse was treated like Dark Hollow Swamp and formed into a narrow pond, called Quarter-Mile Pond, with its overflow to the south.

The location of the road through the woods from the edge of the pond to Woodland Road was carefully studied, in order to save as many trees as possible along the roadside and secure an agreeable alignment. (See Plate VI, Fig. 2.)

The new pumping station is situated a short distance south of Pepe's Cove, where Spot Pond brook leaves the pond. A dam of considerable height was necessary here, but the valley to be cut off was narrow. At its northern end, this dam had to run into a rocky bank slanting steeply away from the pond. At its southern end the ground sloped away much more gently. To save material, and to harmonize with the steep northern bank, the northern landward face of the dam was given a steep slope. This became less steep and swung away from the pond to give room for the pumping station. To the south of the station the form of the dam blended into that of the adjacent hill. The station itself was set almost at the level of the top of the dam, though a little behind it. This has a great advantage, as seen from the other side of the pond. The station appears to be built on the natural shore of the pond, and the trees

FIG. 1. — HALF-MILE ROAD, LOOKING EAST FROM NEAR GATE HOUSE.

FIG. 2. — EXTENSION OF HALF-MILE ROAD, NEAR QUARTER-MILE POND.

FIG. 1. — GATE HOUSE AND BACK OF DIKE AT MORTAR COVE.

FIG. 2. — CONTINUATION OF HALF-MILE ROAD, NEAR WOODLAND ROAD.

behind it conceal the lower land behind the dam. If the station had been placed much below the top of the dam, only its upper story would be visible, thus betraying absolutely the fact that the pond was there held by a dike and giving the building a submerged appearance.

After the construction work which I have roughly indicated, there still remained the problem of planting, the main objects of which were to cover the bare surface of the hills, to block out objectionable views, to frame good views, and to provide shade along the roads. When this work is finished, the pond will be left to itself to gain, by time and natural foliage-growth, that beauty which no skill can give at once.

PROCEEDINGS.

DECEMBER MEETING.

Young's Hotel,
Boston, December 12, 1900.

President Cook in the chair.

The following members and guests were present: —

Members.

L. M. Bancroft, James F. Bigelow, George Bowers, Dexter Brackett, E. C. Brooks, Fred Brooks, G. A. P. Bucknam, George F. Chace, L. Z. Carpenter, John C. Chase, Freeman C. Coffin, Byron I. Cook, Arthur W. Dean, W. W. DeBerard, John W. Ellis, John N. Ferguson, F. F. Forbes, William E. Foss, Frank B. French, Julius C. Gilbert, T. C. Gleason, Albert S. Glover, Amos A. Gould, J. A. Gould, Frank E. Hall, L. M. Hastings, T. G. Hazard, Jr., Horace G. Holden, John L. Howard, Willard Kent, James W. Locke, Cyrus M. Lunt, T. H. McKenzie, Frank E. Merrill, Leonard Metcalf, Frank L. Northrop, W. W. Robertson, Charles E. Riley, Charles W. Sherman, M. A. Sinclair, George A. Stacy, Frederic P. Stearns, William F. Sullivan, Robert J. Thomas, Harry L. Thomas, William H. Thomas, D. N. Tower, W. H. Vaughn, Charles K. Walker, George W. Travis, John C. Whitney, George E. Winslow.

Associates.

Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; George E. Gilchrist, by E. C. Jacobs; Hersey Mfg. Co., by J. A. Tilden and Albert S. Glover; Henry F. Jenks; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Rensselaer Mfg. Co., by Fred S. Bates; Builders' Iron Foundry, by Frederick N. Connet; A. P. Smith Mfg. Co., by William H. Van Winkle; Sumner & Goodwin Co., by Frank E. Hall; Union Water Meter Co., by J. P. K. Otis, A. S. Otis, and F. N. Northrop; United States Cast Iron Pipe and Foundry Co., by John M. Holmes; R. D. Wood & Co., by E. F. Krewson.

Guests.

A. A. Knudson, New York; D. E. Makepeace and George H. Snell, Attleboro, Mass.; Fred V. Fuller, Boston, Mass.; Walter R. Carroll, Brookline, Mass.; Henry W. Lamb, Brookline, Mass.; George M. Nash, Everett, Mass.; Hon. M. R. Leonard, Waltham, Mass.

The Secretary read the following names of applicants for membership: —

For Resident Member.

John O. Hall, Mayor, Quincy, Mass.; George H. Snell, Superintendent of Water Works, Attleboro, Mass.

For Non-Resident Member.

J. William Griffin, Arlington, N. J.; Clinton S. Burns, C.E., Kansas City, Mo.

For Associate.

Harold L. Bond & Co., Construction Work Supplies, 140 Pearl Street, Boston; Lamb & Ritchie, Manufacturers of Tin-Lined Iron Pipe and Lead-Lined Iron Pipe, Cambridgeport.

The Secretary was instructed to cast the ballot of the Association in favor of the applicants named above, which he did, and they were declared elected to membership.

The President appointed as a Committee on Uniform Statistics, Messrs. Joseph E. Beals, of Middleboro; George F. Chace, of Taunton; and John C. Whitney, of Newton; and as a Committee on Standard Specifications for Cast-Iron Pipe, Messrs. Freeman C. Coffin, of Boston; Dexter Brackett, of Boston; and F. F. Forbes, of Brookline.

Mr. A. A. Knudson, Electrical Engineer, New York City, read a paper on "Electrolysis," which called forth discussion and inquiries by the President, and Messrs. Dexter Brackett, Theodore H. McKenzie, Cyrus M. Lunt, John C. Whitney, George E. Winslow, Charles K. Walker, John C. Chase, Frederic P. Stearns, G. H. Snell, Robert J. Thomas, T. C. Gleason, Freeman C. Coffin, Frederick Brooks, George A. Stacy, and F. N. Connet.

On motion of Mr. Brackett, the thanks of the Association were voted to Mr. Knudson for his very interesting and instructive paper.

Adjourned.

PROCEEDINGS.

ANNUAL MEETING.

YOUNG'S HOTEL,
BOSTON, January 9, 1901.

President Cook in the chair.

The following-named members and guests were present: —

MEMBERS.

Charles H. Baldwin, Lewis M. Bancroft, Joseph E. Beals, George Bowers, E. C. Brooks, Frederick Brooks, George F. Chace, John C. Chase, R. C. P. Coggeshall, Byron I. Cook, Henry A. Cook, A. O. Doane, William Downey, F. F. Forbes, William E. Foss, D. H. Gilderson, Albert S. Glover, E. H. Gowing, Frank E. Hall, John O. Hall, L. M. Hastings, T. G. Hazard, Jr., Horace G. Holden, John L. Howard, H. R. Johnson, Willard Kent, C. F. Knowlton, A. E. Martin, Thomas Naylor, Frank L. Northrop, Edward L. Peene, J. B. Putnam, W. W. Robertson, C. E. Riley, H. E. Royce, W. J. Sando, Charles W. Sherman, George H. Snell, R. J. Thomas, H. L. Thomas, William H. Thomas, William W. Wade, Charles K. Walker, G. W. Travis, J. A. Welch, Frank B. Wilkins, C.-E. A. Winslow, George E. Winslow.

ASSOCIATES.

The George F. Blake Mfg. Co., by George J. Foran; Harold L. Bond & Co., by Mr. Bond; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; Hersey Mfg. Co., by James A. Tilden and Albert S. Glover; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Perrin, Seamans & Co., by James C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; A. P. Smith Mfg. Co., by W. H. Van Winkle; Henry F. Jenks; Sumner & Goodwin Co., by Frank E. Hall; Union Water Meter Co., by Frank L. Northrop.

HONORARY MEMBERS.

George H. Frost, Henry C. Meyer.

GUESTS.

J. M. Anderson and M. F. Brennan, Boston, Mass.; George H. Palmer, City Engineer, Palmer, Mass.; John H. Cook, Paterson, N. J.; Charles A.

Claflin, Boston, Mass.; Fred Crosby, Montgomery, Ala.; J. J. Moore, Hingham, Mass.; S. L. Chadbourne, Yonkers, N. Y.; Dr. John H. Washburn, President Rhode Island State College, Kingston, R. I.

The President, in accordance with the provisions of the constitution, declared the polls closed for the election of officers for the ensuing year, and appointed Messrs. Chace, of Taunton, and Winslow, of Waltham, tellers to assort and count the ballots and declare the result.

The following-named were elected to membership: —

Resident Members.

Charles B. Parker, Assistant Superintendent, Cambridge; J. William Kay, Superintendent, Milford; William E. Mayberry, Superintendent, Braintree; J. M. Anderson, Foreman, City Water Department, Worcester; Edward M. Shedd, Inspector, Somerville.

Non-Resident Member.

Charles F. Loweth, Consulting Civil Engineer, St. Paul, Minn.

Associate.

Charles A. Claflin, of Charles A. Claflin & Co., Boston, Steam Engineering and Water-Works Supplies.

REPORT OF THE SECRETARY.

The Secretary, Mr. Willard Kent, submitted the following report, which, on motion of Mr. Coggeshall, was received and ordered to be spread upon the record.

To the President and Members of the New England Water Works Association: — I submit herewith a summary of statistics relating to membership, receipts, and expenditures for the seven months ending December 31, 1901.

Summary of Statistics relating to Membership.

June 1, 1900. Total membership 594

ACTIVE MEMBERS.

June 1, 1900.	Total active membership		519	
	Withdrawals:			
	Resignations	8		
	Dropped	1		
	Died	2	11	
			508	
	Initiations:			
	June	4		
	September	9		
	November	5		
	December	4	22	530

HONORARY MEMBERS.

June 1, 1900.	Honorary members	5	
	Died	1	4

ASSOCIATES.

June 1, 1900.	Total associate membership		70	
	Withdrawals:			
	Died		1	
			69	
	Initiations:			
	June	1		
	December	2	3	72

January 1, 1901.	Total membership	606
	Net gain in membership	12

Summary of Receipts from June 1, 1900, to January 1, 1901.

Balance from former Secretary	$612.49
Initiations	98.00
Subscriptions and sale of Journals	155.70
Advertisements	880.00
Dues	1 219.75
Sundry	132.18
	$3 098.12

Summary of Expenses from June 1, 1900, to January 1, 1901.

Rent	$300.00
Junior Editor	250.00
Assistant Secretary	200.00
Secretary	166.67

Stenographer (reporting meetings)	$119.35
June excursion	94.50
Stereopticon	53.91
Music	40.00
Badges	31.60
Expenses of Committee on Exhibit of Associate Members	25.50
JOURNAL	1 252.21
Printing, stationery, postage, express, and sundry incidentals	294.47
	$2 828.21

Respectfully submitted,

WILLARD KENT, *Secretary*.

REPORT OF THE TREASURER.

The Treasurer, Mr. Bancroft, submitted the following report, which was received and placed on file : —

LEWIS M. BANCROFT, TREASURER,

In account with New England Water Works Association.

RECEIPTS.

1900.				
June 1.	Balance on hand			$1 270.40
9.	Received of Willard Kent, Sec'y		$154.90	
16.	" " " " "		564.55	
25.	" " " " "		162.75	
July 9.	" " " " "		110.00	
24.	" " " " "		198.00	
August 22.	" " " " "		210.75	
September 11.	" " " " "		193.38	
13.	" " " " "		612.49	
	" " " " "		50.75	
October 8.	" " " " "		164.75	
20.	" " " " "		197.75	
November 7.	" " " " "		171.15	
26.	" " " " "		151.50	
December 19.	" " " " "		155.40	3 098.12
	Received interest on deposit, People's Savings Bank, Worcester			65.67
				$4 434.19

EXPENDITURES.

1900.		
June 7.	Willard Kent, salary and expenses	$64.50
11.	Charles W. Sherman, salary and expenses . . .	89.50
	Evening Post, electrotype	.50
14.	John Chamberlain, floral tribute late J. C. Haskell	10.00
25.	L. M. Bancroft, revenue stamps	2.48
	Boston Society Civil Engineers, rent to June 1 .	100.00
	J. M. Ham, salary to June 15, stamps and express	28.92
	Samuel Usher, printing JOURNAL	309.50
26.	C. H. Curtis, caterer	44.50
July 10.	Samuel Hobbs & Co., stationery	3.92
25.	J. M. Ham, salary to July 15, express, etc. . . .	26.28
August 23.	P. S. Keating, barges, June meeting	50.00
	Samuel Usher, printing	7.25
September 6.	American Society Civil Engineers, binding . . .	2.40
	Charles W. Sherman, salary and expenses to September 1	83.06
	Boston Society Civil Engineers, rent to September 1	100.00
	W. T. Almy, badges	31.60
	Willard Kent, salary and expenses to September 1	85.00
10.	J. M. Ham, salary and expenses to August 15 . .	28.33
29.	Henry F. Jenks, expenses committee on exhibits at nineteenth annual convention	25.50
	Thomas P. Taylor, stereopticon, nineteenth annual convention	33.91
October 9.	J. M. Ham, salary to September 15, expenses nineteenth annual convention	50.25
	W. N. Hughes, printing	1.75
	Samuel Usher, printing JOURNAL and Constitution	392.30
25.	D. Gillies' Sons, printing	55.50
	J. M. Ham, salary to October 15	25.00
November 9.	Bacon & Burpee, report of September meeting .	91.85
	D. Gillies' Sons, printing	32.25
19.	Tremont Temple, directory card	.35
	W. N. Hughes, numbering machine	12.00
	Willard Kent, rebate to J. C. Whitney, for sundry payments	14.00
	Francis L. Pratt, music, November meeting . .	20.00
27.	Hub Engraving Co., plates	57.03
30.	Joseph E. Beals, services and expenses, Senior Editor	40.00
	J. M. Ham, salary to November 15, postage and express	29.85

	Thomas P. Taylor, stereopticon	$10.00
December 17.	D. Gillies' Sons, printing	54.00
	Charles W. Sherman, salary to December 1, postage and express	84.05
	Willard Kent, salary to December 1, postage and express	69.34
18.	Francis L. Pratt, music, December meeting . .	20.00
	Boston Society Civil Engineers, rent to December 1	100.00
21.	J. M. Ham, salary and express	27.25
	Thomas P. Taylor, stereopticon	10.00
	Samuel Hobbs & Co., stationery	2.03
		$2 325.95

BALANCE ON HAND.

Deposit, People's Savings Bank, Worcester	$1 249.70	
Deposit, First National Bank, Reading	858.54	2 108.24
		$4 434.19

LEWIS M. BANCROFT, *Treasurer.*

READING, January 1, 1901.

John H. Washburn, Ph.D., President of the Rhode Island College of Agriculture and Mechanic Arts, gave an interesting talk on "Some of the Physiographic Features which affect our Water Supply," illustrated by a large number of lantern slides.

Mr. W. J. Sando, Manager International Steam Pump Co., Brooklyn, N. Y., contributed a paper descriptive of the Metropolitan Water Works Pumping Machinery.

Mr. Chace, for the committee to assort and count the ballots for officers for the ensuing year, made the following report: —

For President.

F. H. CRANDALL, Burlington, Vt. 159

For Vice-Presidents.

CHARLES K. WALKER, Manchester, N. H. 157
JAMES BURNIE, Biddeford, Me. 145
WILLIAM E. HAWKS, Bennington, Vt. 147
F. E. MERRILL, Somerville, Mass. 152
T. G. HAZARD, Jr., Narragansett Pier, R. I. 145
CHARLES E. CHANDLER, Norwich, Conn. 144

For Secretary.

Willard Kent, Narragansett Pier, R. I.	160

For Treasurer.

L. M. Bancroft, Reading, Mass.	161

For Editor.

C. W. Sherman, Boston, Mass.	160

For Advertising Agent.

R. J. Thomas, Lowell, Mass.	157

For Additional Members of Executive Committee.

P. Kieran, Fall River, Mass.	151
George A. Stacy, Marlboro, Mass.	152
D. N. Tower, Cohasset, Mass.	147

For Finance Committee.

A. W. F. Brown, Fitchburg, Mass.	157
W. F. Codd, Nantucket, Mass.	156
J. W. Crawford, Lowell, Mass.	154

Total ballot	161
Blanks	2
	163

On motion of Mr. Thomas, of Lowell, the thanks of the meeting were voted to Dr. Washburn and to Mr. Sando for their able, interesting, and instructive papers.

Adjourned.

PROCEEDINGS.

FEBRUARY MEETING.

YOUNG'S HOTEL,
BOSTON, February 13, 1901.

President Crandall in the chair.

The following members and guests were in attendance: —

MEMBERS.

Charles H. Baldwin, Lewis M. Bancroft, Joseph E. Beals, George Bowers, Roland Barnes, Fred. Brooks, George Cassell, George F. Chace, G. L. Chapin, John C. Chase, William F. Codd, Freeman C. Coffin, F. H. Crandall, Arthur W. Dean, John W. Ellis, B. R. Felton, F. F. Forbes, Frank L. Fuller, Frank E. Fuller, William E. Foss, E. V. French, Julius C. Gilbert, J. F. Gleason, Albert S. Glover, William R. Groce, Frank E. Hall, J. C. Hammond, Jr., John O. Hall, L. M. Hastings, T. G. Hazard, Jr., Horace G. Holden, Willard Kent, James W. Locke, C. F. Knowlton, Frank E. Merrill, Leonard Metcalf, H. N. Parker, J. B. Putnam, W. W. Robertson, William T. Sedgwick, P. P. Sharples, Charles W. Sherman, Sidney Smith, John D. Shippee, George A. Stacy, George H. Snell, Robert J. Thomas, William H. Thomas, W. F. Sullivan, W. H. Vaughn, W. W. Wade, C.-E. A. Winslow, C. K. Walker, John C. Whitney.

ASSOCIATES.

Harold L. Bond & Co., by Mr. Bond; Chadwick Lead Works, by A. H. Broderick; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; Charles A. Claflin & Co., by Mr. Claflin; Hersey Mfg. Co., by James A. Tilden and Albert S. Glover; Henry F. Jenks; Lead Lined Iron Pipe, by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by J. G. Lufkin and Charles H. Baldwin; Neptune Meter Co., by H. H. Kinsey; Lamb & Ritchie, by George M. Nash; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; Builders Iron Foundry, by W. C. Buell; Sumner & Goodwin Co., by Frank E. Hall; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by J. K. P. Otis and Frank L. Northrop; United States Cast Iron Pipe & Foundry Co., by John M. Holmes; R. D. Wood & Co., by E. F. Krewson.

GUESTS.

J. F. Carmichael, Lowell, Mass.; Julian P. Wood, Marlboro, Mass.; Thomas H. Naughton, Somerville, Mass.; George E. Hersey, Superintendent, Whitman, Mass.; Amos H. Eaton, Chr., Middleboro, Mass.; Mr.

Edwards, Londonderry, N. S.; Prof. W. H. Niles, Boston, Mass.; George W. Babcock, Assistant Superintendent, Attleboro, Mass.; Prof. W. M. Davis, Cambridge, Mass.; Dr. George W. Field, Massachusetts Institute of Technology, Boston, Mass.; A. D. Flinn, Boston, Mass.; Fred A. Beals, Everett, Mass.; Macy S. Pope and E. P. Walters, Boston, Mass.; A. C. Grover, City Engineer, Rutland, Vt.

The following applications were received, having been approved by the Executive Committee: —

For Resident Member.

Charles N. Taylor, C.E., Wellesley, Mass.

For Associate.

Barr Pumping Engine Co., Philadelphia, Pa.

On motion, the Secretary was directed to cast the ballot of the Association in favor of the applicants, and they were declared elected.

Mr. William R. Groce called the attention of members to House Bill No. 498, "To provide that unpaid water rates shall be a lien upon the estate," now before the Massachusetts legislature, and to the fact that there would be a hearing upon this bill before the Committee on Judiciary of the Legislature on February 15 at the State House.

Prof. William T. Sedgwick, Professor of Biology, Massachusetts Institute of Technology, presented a paper entitled "The Rise and Development of Water Supply Sanitation in the Nineteenth Century," which was discussed by Messrs. George F. Chace and E. V. French.

A paper on "The Causes of Rainfall" was presented by Prof. W. M. Davis, of Harvard College, and was discussed by Prof. William H. Niles, of the Massachusetts Institute of Technology, and Messrs. George F. Chace, Charles W. Sherman, Fred. Brooks, Charles K. Walker, John C. Chase, Sidney Smith, and J. C. Hammond, Jr.

Discussion on the subject of "Charges for Private Fire Service" was opened by Mr. J. C. Hammond, Jr., and was continued by Messrs. Charles K. Walker and E. V. French. Further discussion on this topic was postponed until the next meeting.

Adjourned.

OBITUARY.

Mellen S. Harlow, who was elected to Associate membership in this Association on December 11, 1895, died at Faulkner, Mass. December 29, 1900.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XV. June, 1901. No. 4.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

METROPOLITAN WATER WORKS PUMPING MACHINERY.

BY WILL J. SANDO, UNTIL RECENTLY SUPERINTENDENT OF PUMPING STATIONS, METROPOLITAN WATER WORKS, BOSTON, MASS.

[*Read January 9, 1901.*]

On the first day of January, 1898, the Metropolitan Water Board began supplying the Metropolitan District with water. The pumping stations controlled and operated by the board at that time, two in number, were located at Chestnut Hill Reservoir and Melrose. The pumping equipment consisted of machinery having an aggregate daily capacity of 36 000 000 United States gallons, representing about 1 050 horse power.

To-day the board controls and operates five pumping stations, located as follows: two at Chestnut Hill Reservoir, one for the high service and one for the low service; one at Spot Pond (this station superseded the one at Melrose); one at Arlington; and one at West Roxbury (the latter leased from the city of Boston). There is also a pumping station at Clinton, Mass., used for pumping sewage, which will not be considered at this time. The aggregate daily capacity is 203 380 000 gallons in twenty-four hours, representing about 3 775 horse power.

The principal dimensions of the engines and boilers in the several pumping stations are given in Tables Nos. 1 and 2.

The cost of pumping one million gallons of water one foot high during the year 1899 ranged from 2.3 cents to 30.9 cents.

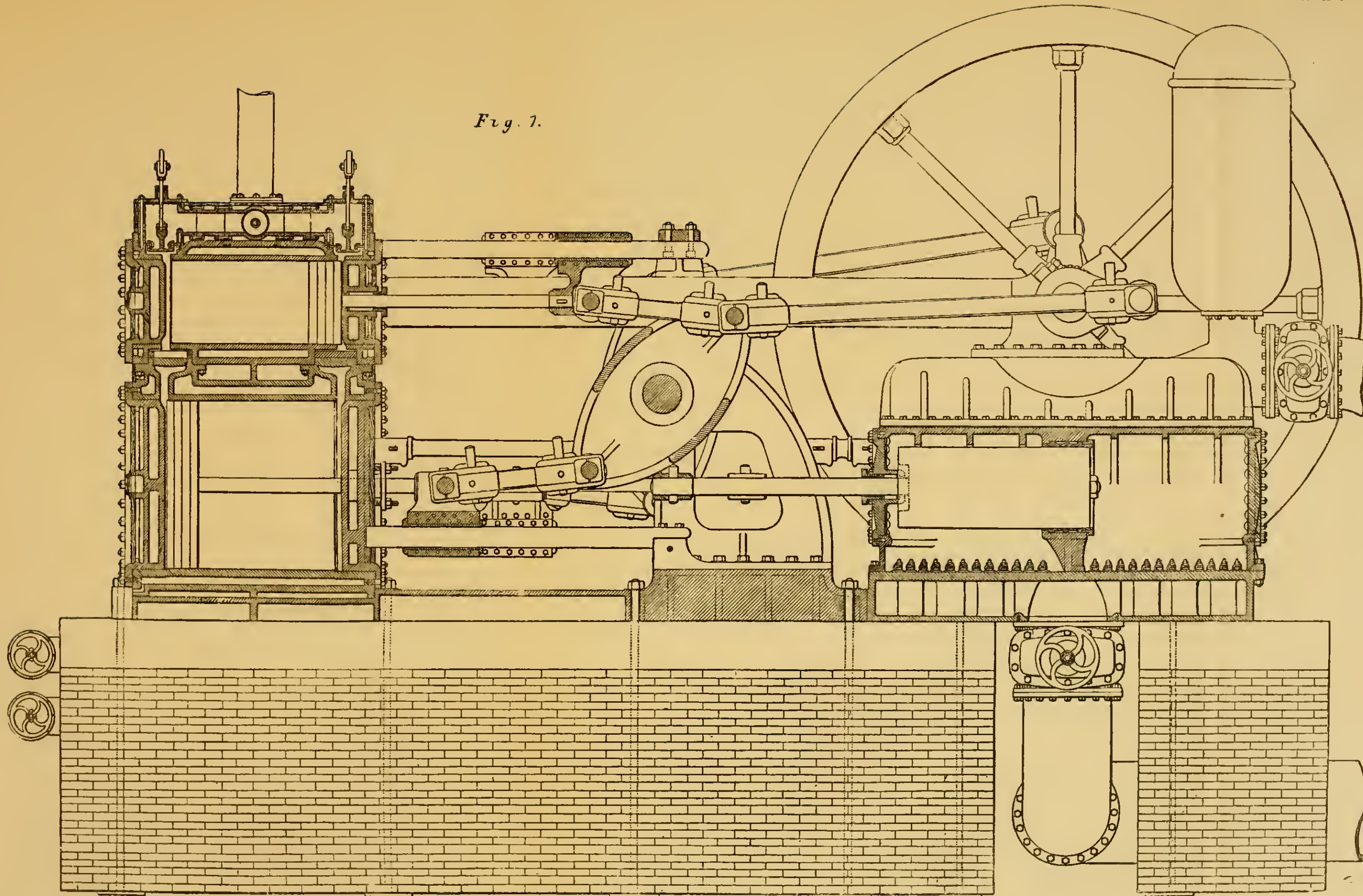
At the present time the Chestnut Hill High-Service Station is best known to the majority of our members and engineers in general.

Engines Nos. 1 and 2, designed and built by the Holly Manufac-

TABLE No. 1. — PRINCIPAL DIMENSIONS OF ENGINES.

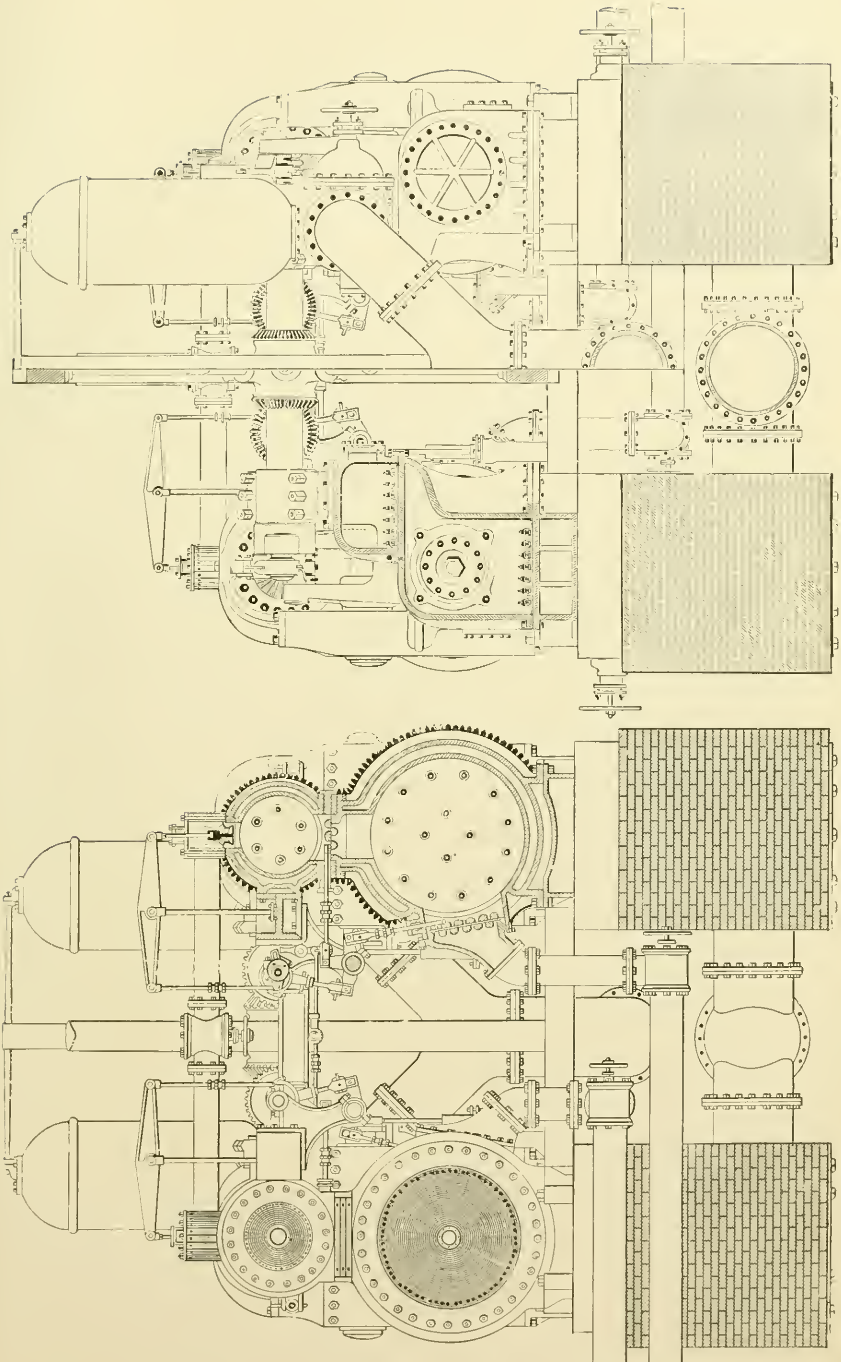
Pumping Station.	Engine.	Diameter of Steam Cylinders (Inches).	Stroke of Pistons (Inches).	Diameter of Pump Plungers (Inches).	Stroke of Pump Plungers (Inches).	Normal Speed (Revolutions per minute).	Builder.	Capacity in 24 Hours (Gallons).
Chestnut Hill High Service.	No. 1	21 H. P. 21 H. P. 42 L. P. 42 L. P.	36	25 D. A.	36	18½	Holly Mfg. Co.	8 000 000
	No 2	21 H. P. 21 H. P. 42 L. P. 42 L. P.	36	25 D. A.	36	18½	Holly Mfg. Co.	8 000 000
	No. 3	13.7 H. P. 24.375 I. P. 39.0 L. P.	72	17.5 D. A.	48	50	Quintard Iron Works.	20 000 000
	No. 4	30 H. P. 56 I. P. 87 L. P.	66	42 S. A.	66	18	E. P. Allis Co.	30 000 000
Chestnut Hill Low Service.	No. 5	17 H. P. 31¼ I. P. 48 L. P.	60	37 S. A.	60	30	Holly Mfg. Co.	35 000 000
	No. 6	17 H. P. 31¼ I. P. 48 L. P.	60	37 S. A.	60	30	Holly Mfg. Co.	35 000 000
	No. 7	17 H. P. 31¼ I. P. 48 L. P.	60	37 S. A.	60	30	Holly Mfg. Co.	35 000 000
Spot Pond.	No. 8	21 H. P. 42 L. P.	48	14⅞ & 21 Dif.	48	51	Geo. F. Blake Mfg. Co.	10 000 000
	No. 9	22 H. P. 41½ I. P. 62 L. P.	60	30½ S. A.	60	25	Holly Mfg. Co.	20 000 000
Arlington.	No. 10	16 H. P.	12	9 D. A.	12	40	Geo. F. Blake Mfg. Co.	750 000
	No. 11	9 H. P. 18 L. P.	12	9 D. A.	12	40		750 000
West Roxbury.	No. 12	10 H. P.	12	7 D. A.	12	40	Geo. F. Blake Mfg. Co.	440 000
	No. 13	10 H. P.	12	7 D. A.	12	40		440 000

H. P., High Pressure.
I. P., Intermediate Pressure.
L. P., Low Pressure.
D. A., Double Acting.
S. A., Single Acting.
Dif., Differential.



Sectional Elevation, Engine No. 1 or No. 2.

PLATE II.



Elevation and Section, Steam End.

Elevation and Section, Pump End.

Engine No. 1 or No. 2.

turing Company, Lockport, N. Y., were erected in 1887, and they were tested in August and September, 1888. Plate I shows a longitudinal section, and Plate II, cross sections of these engines. Boilers Nos. 1 and 2, of the return tubular type, designed by the City Engineer's Department of Boston, and built by George Miles, Boston, were used for supplying steam. The engines fulfilled the builder's guarantee for economy, and the boilers, including feed water heater, on a subsequent test, December 4 and 5, 1890, made a record of 12.14 pounds of water evaporated per pound of coal from

TABLE No. 2.—PRINCIPAL DIMENSIONS OF BOILERS.

Pumping Station.	Boilers.	Diameter (Feet and Inches).	Length (Feet and Inches).	Number of Tubes.	Size of Tubes (Inches).	Heating Surface (Sq. Ft.).
Chestnut Hill High Service.	No. 1	6′ - 6″	18′ - 6″	151	3	2 171
	No. 2	6′ - 6″	18′ - 6″	151	3	2 171
	No. 3	7′ - 6″	34′ - 4″	201	3	3 000
	No. 4	7′ - 6″	34′ - 4″	201	3	3 000
Chestnut Hill Low Service.	No. 5	8′ - 2″	24′ - 11⅝″	378	2	2 897
	No. 6	8′ - 2″	24′ - 11⅝″	378	2	2 897
	No. 7	8′ - 2″	24′ - 11⅝″	378	2	2 897
Spot Pond.	No. 8	7′ - 8″	26′ - 11¾″	256	2¼	2 295
	No. 9	7′ - 8″	26′ - 11¾″	256	2¼	2 295
	No. 10	7′ - 8″	26′ - 11¾″	256	2¼	2 295
Arlington.	No. 11	4′ - 8″	18′ - 0″	60	3½	937
West Roxbury.	No. 12	3′ - 6″	8′ - 0″	85	1⅞	300
	No. 13	3′ - 6″	8′ - 0″	85	1⅞	300

and at 212°. That record has not, to the writer's knowledge, been equaled by the same type of boilers under similar conditions.

Next came the No. 3 engine, designed by E. D. Leavitt, M.E., and built by the Quintard Iron Works, New York.* This engine was new in design, and especially interesting on account of the unusually high steam pressure, 185 pounds per square inch, and the mechanically operated pump valves which make it possible to run at

*This engine was described by Mr. Leavitt in a paper entitled "A Few Examples of High Grade Pumping Engines," presented to this Association, June 15, 1894, and printed in the JOURNAL for March, 1895, Vol. IX, p. 163. Plates VII and VIII accompanying that paper illustrate engine No. 3, and Plate IX shows boiler No. 3.

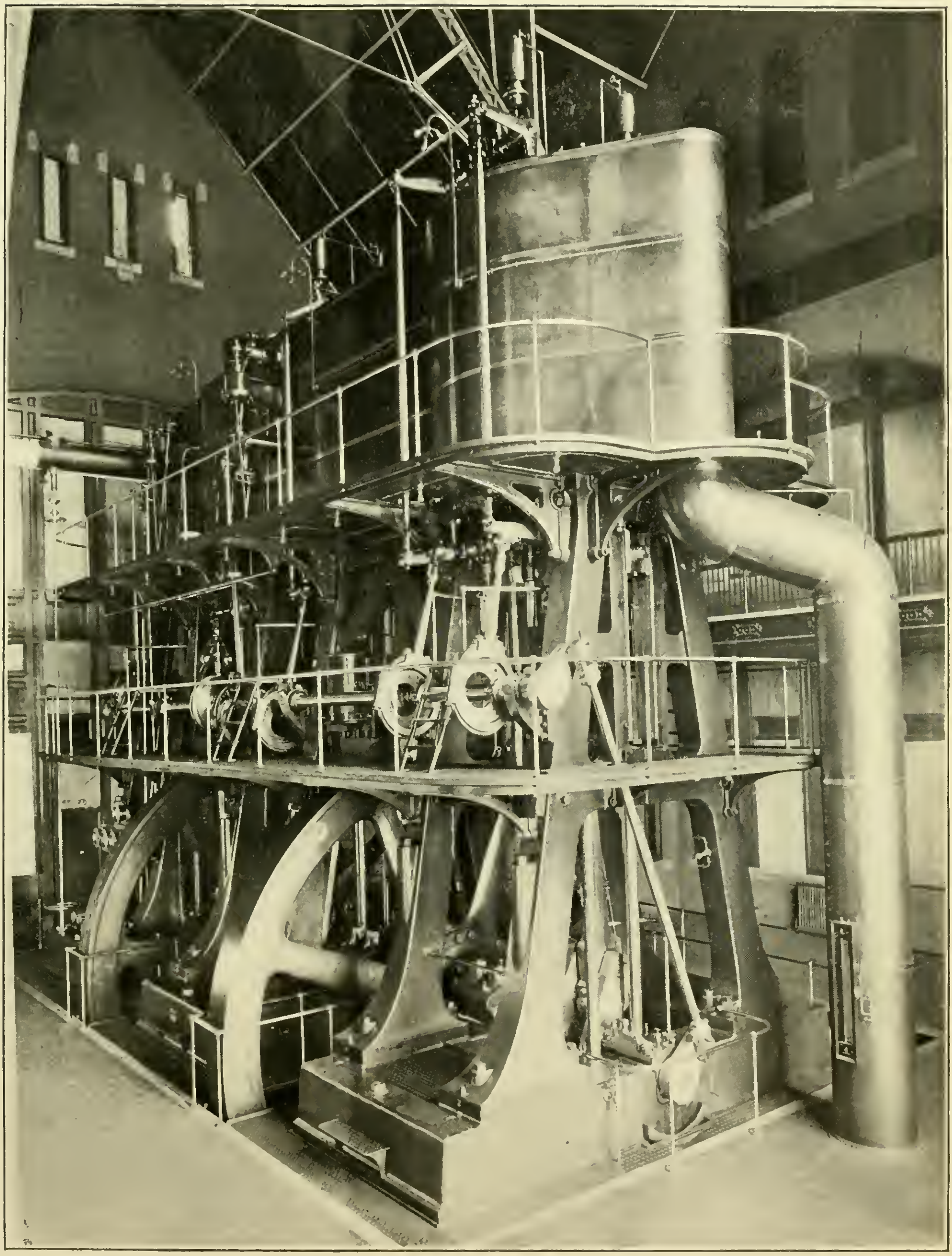
very high speed. This engine has been operated smoothly and economically at 70 revolutions per minute, the corresponding plunger speed being 490 feet per minute, or 40 per cent. in excess of the nominal contract speed. The conditions were such that it was necessary to design the engine to occupy a certain space in the existing building, which made the proposition rather more difficult than building an engine regardless of floor space. This engine was tested May 1 and 2, 1895, and had not, previous to the test, been run for more than seven consecutive hours. The engine had been very carefully built, and care exercised in aligning and erecting, but did not have the advantage of being limbered up by continuous running. However, under such unfavorable conditions, a record of 11.22 pounds of steam per indicated horse power per hour was established. Boiler No. 3, of the Belpaire type, designed by Mr. Leavitt and built by the Atlantic Works, East Boston, was used for supplying steam.

Table No. 3 gives the data and cost of operating the No. 3 engine for the year 1898.

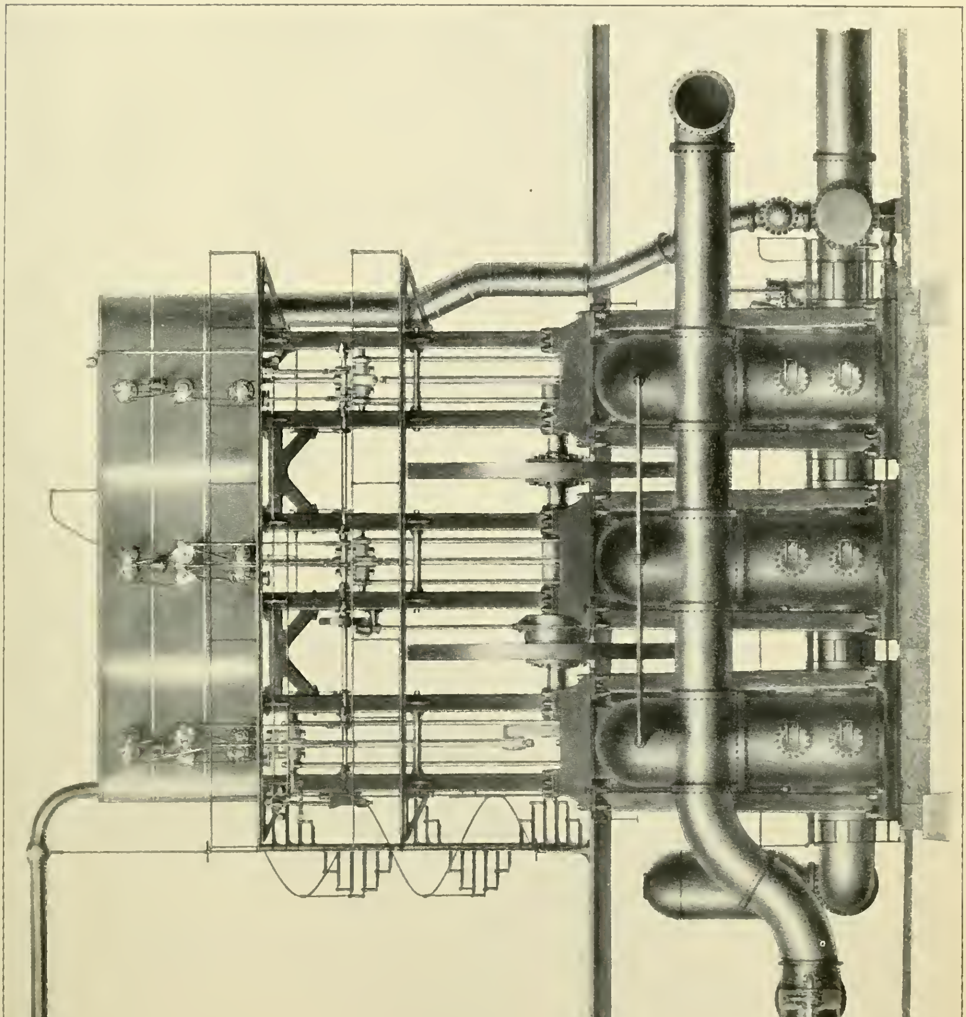
TABLE No. 3.

Data on Operation of Engine No. 3 at the Chestnut Hill High-Service Pumping Station for the Year 1898.

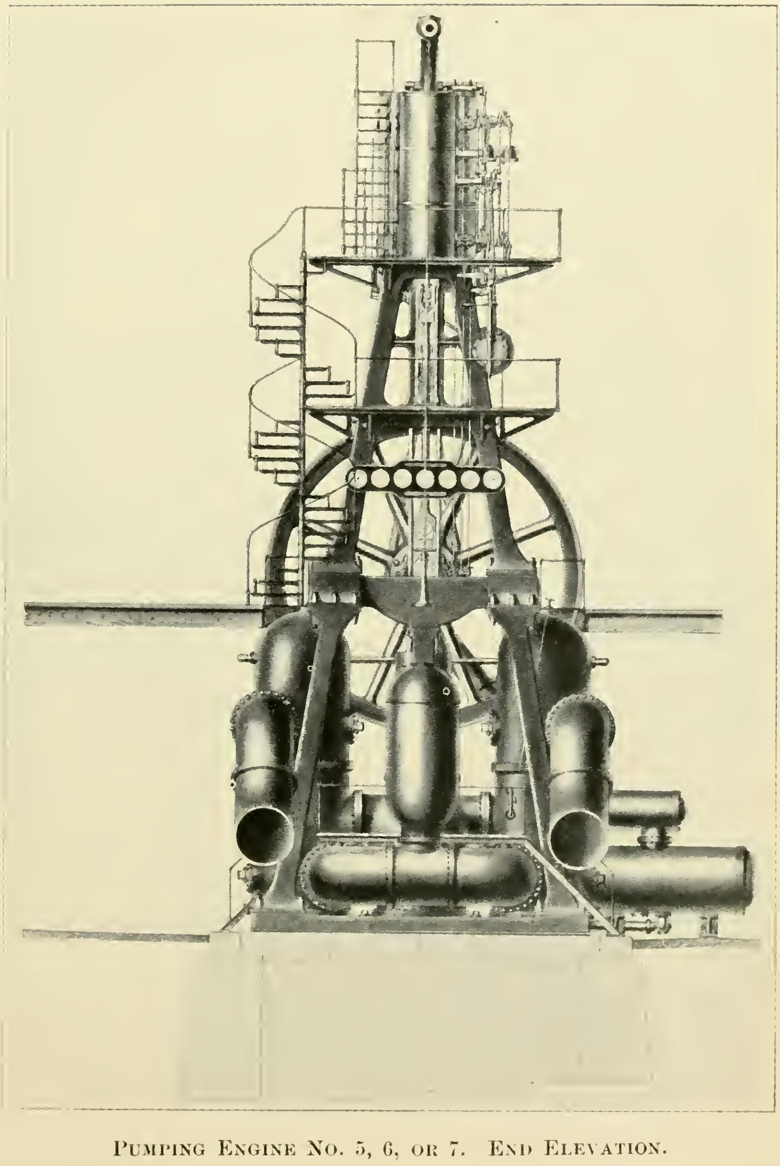
1. Total days run	365
2. Total hours run	8 542.5
3. Average hours run per day	23.4
4. Total gallons pumped (3 per cent. allowed for slip)	6 404 700 000
5. Average gallons pumped per day (3 per cent. allowed for slip)	17 547 000
6. Average gallons pumped per day (plunger displacement)	18 073 000
7. Average head pumped against (feet)	126.81
8. Total coal burned	5 901 061 lbs.
9. Duty on total coal (slip allowed)	114 790 000
10. Duty on total coal (plunger displacement)	118 370 000
11. Coal: Georges Creek, Cumberland, and New River.	
12. Cost of coal per ton (2240 lbs.)	$3.69
13. Total ash and clinker	425 278 lbs.
14. Per cent. ash and clinker	7.2
15. Pounds of coal to raise 1 000 000 gals. 126.81 ft. high	921
16. Cost of coal to raise 1 000 000 gals. 126.81 ft. high	$1.52
17. Pounds of coal to raise 1 000 000 gals. 1 ft. high	7.26
18. Cost of coal to raise 1 000 000 gals. 1 ft. high	$0.01
19. I. H. P. of engine	446
20. Coal per I. H. P. per hour	1.55 lbs.



Pumping Engine No. 4. Capacity, 30 000 000 Gallons per Day.



Pumping Engine No. 5, 6, or 7. Side Elevation.



Pumping Engine No. 5, 6, or 7. End Elevation.

21. Cost of coal per I. H. P. per year, running 24 hours per day (365 days, calendar year) $22.37
22. Cost of yearly H. P., running 24 hours per day (total maintenance) $47.72

The next engine was No. 4, designed and built by the Edward P. Allis Company, of Milwaukee, Wis. (see Plate III). This engine was also designed for a steam pressure of 185 pounds per square inch, and on the official test, May 1 and 2, 1900, — six years to a day after the test of the No. 3 engine, — made a new record of 10.479 pounds of steam per indicated horse power per hour. On this test the No. 4 boiler, including economizer, evaporated 12.478 pounds of water per pound of coal from and at 212°. This boiler is also of the Belpaire type, and was designed by Mr. Leavitt and built by the Lake Erie Boiler Works, Buffalo, N. Y. It is equipped with American mechanical stokers. A duty of 169 000 000 foot pounds for every 100 pounds of coal burned is not an uncommon weekly duty for the No. 4 engine when supplied with steam from the No. 4 boiler. Conditions are such at this station that records can be kept absolutely, without having to make allowances for auxiliary machinery. The credit for this economy is due not only to the combination of good engine design, good boilers, stokers, and economizers, but a considerable share of it belongs to the station corps of engineers and firemen.

There cannot at the present time be anything said concerning the economy of engines Nos. 5, 6, and 7 at the low-service station, and engine No. 9 at Spot Pond, which were designed and built by the Holly Manufacturing Company, of Lockport, N. Y., as none of them has been officially tested. However, it may be said that these engines have all been running several months, and each engine was turned over to the station corps of engineers to operate in less than twenty-four hours after the first start. They are all vertical triple-expansion engines, of the self-contained type (see Plates IV and V).

Engine No. 6 was started first at 4.20 P.M., July 2, 1900, and was operated by the contractor's men until 8 A.M. the following morning, when it was turned over to the station engineers; and beginning July 5, it was run continuously for twenty-four days. It was then stopped to put on the lagging.

The specifications for the low-service engines required the contractor to guarantee 145 000 000 foot pounds duty for each 1 000 pounds of commercially dry steam used by the engine and its auxiliaries

when delivering 35 000 000 gallons of water in twenty-four hours against a dynamic head of 45 feet, with a steam pressure of not more than 150 pounds per square inch at the throttle. This is the highest duty ever specified under similar conditions to the knowledge of the writer, and has not yet been accomplished by any engine officially tested.

The pumps are of special design, and the first of the kind built. Although these engines have not been officially tested, the weekly station duty indicates that the guarantee will be fulfilled, and there may be a little to spare. The highest weekly station duty thus far recorded on 100 pounds of coal is, in round numbers, 134 000 000 foot pounds. The boilers for supplying steam to engines Nos. 5, 6, and 7 were designed by Messrs. Dean & Main, of Boston, and built by the Atlantic Works. They are of the vertical fire tube type, and are expected to give very good results.

It may be fair to assume that the boilers are now evaporating, under actual conditions, nine pounds of water per pound of coal; on this basis the engines are doing about 149 000 000 foot pounds duty on the basis of 1 000 pounds of steam.

Engine No. 9 at Spot Pond is similar in design to engines Nos. 5, 6, and 7. The contract head is 125 feet, and the specified duty 150 000 000 foot pounds for each 1 000 pounds of commercially dry steam. This engine is expected to exceed the guaranteed duty considerably.

The boilers at this station are of the same type as those at the low-service station. They were designed by Dean & Main, and built by the Lake Erie Boiler Works, of Buffalo, N. Y.

The No. 8 engine was designed by Mr. Leavitt, and built by the George F. Blake Manufacturing Company for the Boston Water Works, and was originally erected at the Mystic Pumping Station, and subsequently moved to Spot Pond. This engine was described by Mr. Leavitt in the paper already referred to, and is illustrated in Plate VI accompanying that paper. Some slight alterations have been made to adapt the engine to the new conditions.

Engines Nos. 10, 11, 12, and 13 are of the standard types built by the George F. Blake Manufacturing Company.

SERVICE BOXES.

[A General Discussion at the Meeting of November 14, 1900.]

The President.* The topic for discussion this afternoon is service boxes, and we would like to learn from the members what they regard as an ideal service box from the superintendent's standpoint; one that is available in summer as well as in winter, one which can be placed with safety in a curbed street as well as in the outside limits of the city, and one that is easily accessible at any time. I will call on Mr. Martin, of South Framingham, for his idea of an up-to-date service box.

Mr. A. E. Martin.† Mr. President, I think you have called on a poor man for information on this subject. I have always used the Bingham & Taylor box. I do not consider it an ideal one by any means, but it is the only box I have ever used, although a good many different service boxes have been sent to me. I think you had better call upon somebody who has had more experience than I have.

The President. Possibly Mr. Walker, of Manchester, can give us some light. It is a good while since we have heard anything from the Granite State.

Mr. C. K. Walker.‡ I can't give you any light to-day, I am afraid. My lamp is hid under a bushel.

The President. You can tell us what kind of service box you use in Manchester.

Mr. Walker. I guess I use the same kind that almost everybody does, — the telescopic kind, made in the first place by "Jerekiah" Hayes, out in Erie, Pa. It is a simple concern, with a handle coming up within about a foot of the top. You don't very often have to use them, but if you don't have them well located in the winter time it makes some hard feeling. If they are well located, however, they are easily got at, and you can shut the water off when necessary.

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* Byron I. Cook, Superintendent, Woonsocket Water Works.
† Superintendent, Framingham Water Company.
‡ Superintendent, Manchester Water Works.

I think it is the cheapest thing there is, because it does n't cost but a dollar, delivered complete. That is what we have been using for the last ten years. I have seen some patented devices, all good enough if people like them, but I have n't seen anything that suits me any better than the old kind. And you know it is a good deal with us as it is with the farmer; if he has a mowing machine that does the work well he sticks to that kind, although there may be a better kind. Our service box is cheap and satisfactory, and has done good service. I can't give you any further light on the subject, although I may say I have done some swearing when I could n't find a box, but that was n't any fault of the box; the box was all right.

THE PRESIDENT. Possibly Mr. Merrill, of Somerville, can give us some light with regard to a patented service box.

MR. FRANK E. MERRILL.* I came here to-day to see if I could n't find out what the ideal service box is, for I don't think I have got it yet. The box that we use has a cast-iron bottom and telescopic top, made of two-inch plain pipe, with an iron top which screws on, and a cover that is secured by a brass nut. (See Fig. 1.) We make up the boxes in our own shop, as we have the opportunity, and the cost is light. As Mr. Walker says, the ordinary box is all right as long as you know where it is, and that, I think, is really the main point. Our covers have a beveled edge, so people are not apt to stub their toes on them. That is something we have to be very careful to prevent. Aside from that I don't know that our box is any better than many others, but it gives us good satisfaction.

MR. A. E. MARTIN. I should like to state, Mr. President, that I think we have one service box which is among the most expensive in the country. I should hope there were very few, at least, that ever cost a water company or a water department any more than that one cost us. The original price was something like a dollar and a quarter, but for the privilege of locating it in a certain place we paid one of our citizens about three hundred dollars. He asked for one thousand dollars, but we finally compromised the matter with him for about three hundred dollars. That service box stood up above the sidewalk just the thickness of my finger. A party came into my office one morning and informed me that a lady had fallen over the box the night before and sprained her arm so badly that probably we would have trouble about it. I immediately went out and located the box, and found that there was some question whether

* Water Commissioner, Somerville, Mass.

she stumbled over the box or the curbstone; but the doubt was, of course, on our side, for we would have to prove that she did n't stumble over the box, and so, in order not to have any more trouble about it, we settled the case before it had gone very far in the

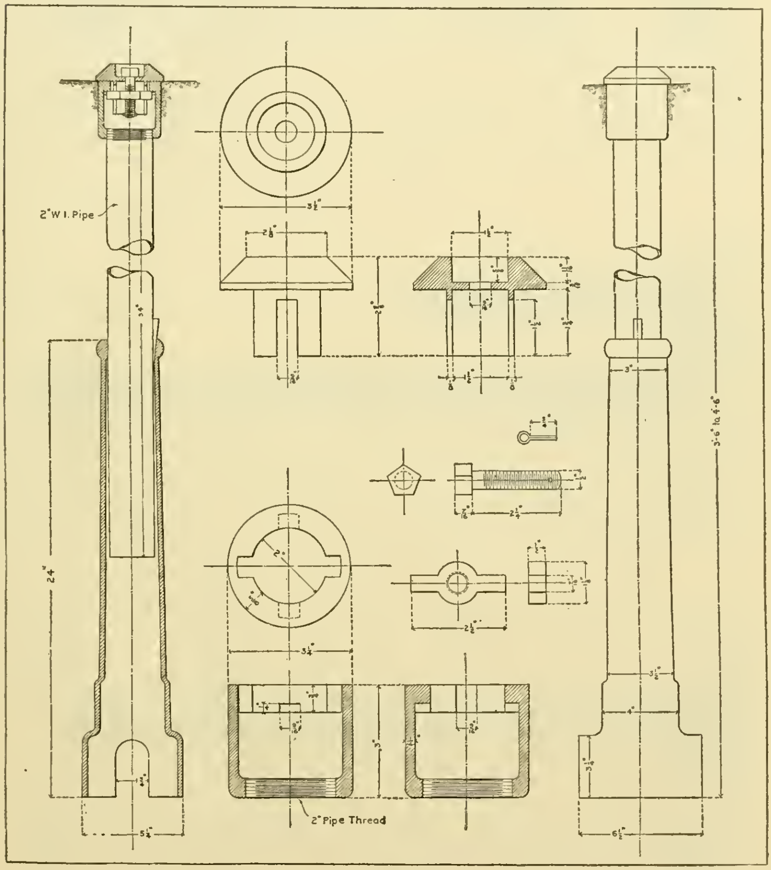

FIG. 1. — SERVICE BOX, SOMERVILLE WATER WORKS.

courts. The sidewalk was sloping, more so than is usual in most cases, and the lower edge of the box stood up, as I have said, just about the thickness of my finger. Mr. Merrill's statement that his boxes have a beveled edge brought this circumstance to my mind.

THE PRESIDENT. I will say in regard to the Bingham & Taylor

service box that the fault I find with it is that in some soils in the spring of the year the frost is liable to throw it, and it is often impossible to get it back into its original position without breaking it. A service box for use in such a soil must be telescopic, something which can be driven back again. Another trouble with the Bingham & Taylor service box is that the thread on the iron casting on the inside is liable to deteriorate, and in a short time the brass nut which clamps the cover to the top will fail to work and a new top is required. The service box I use is telescopic, with a slot in the side, and the cover is clamped by making a thread in the brass bushing, which is held by a brass wire to prevent running off. (See Plate I, Fig. 1.) So far I have had excellent results with it. I would call on Mr. Coggeshall, of New Bedford, to give us his idea in regard to a service box.

Mr. R. C. P. Coggeshall.* I am afraid that I cannot give much light upon the subject. The box now in use in New Bedford was designed some twenty years ago for our especial use. We had had a great deal of trouble from the very cause of which you have spoken, that is, lifting by frost. I have known a box to rise five inches above grade. Then, again, any one could remove the cover, and mischievous parties often did so; consequently many boxes were found more or less filled when needed for use. The box which we now use is made in three castings, — the base, the upright, and the cover. (See Plate I, Fig. 2.) The upright casting telescopes over the outside of the base casting. The frost may lift this upright, but it requires very little pressure to return it to its proper position when the frost leaves the ground. The cover covers the whole tube, and is fastened to the upright by a composition screw which goes through the cover and enters a composition nut fastened to the upright. It has been a very satisfactory stop box.

The President. We have a representative with us to-day from the Builders Iron Foundry. They have just begun the manufacture of a service box which they think is all right, and I would call on Mr. Connet for a description of it.

Mr. F. N. Connet. The model which I have before me is a model of the Stacy box, invented by one of your members. (See Fig. 2; also Plate I, Fig. 3.) One of the principal features about it is that it lacks some of the patented features of others. Many service boxes have the telescope joint threaded, and it has been

* Superintendent, New Bedford Water Works.

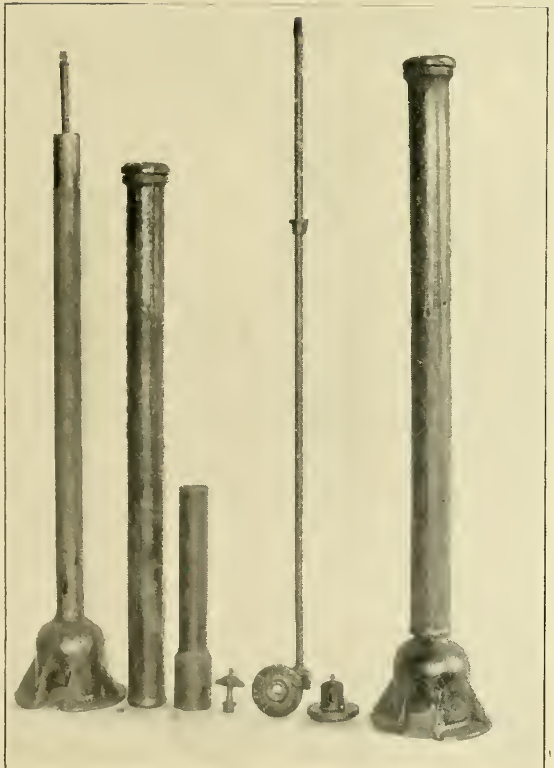

Fig. 1. — Woonsocket Service Box.

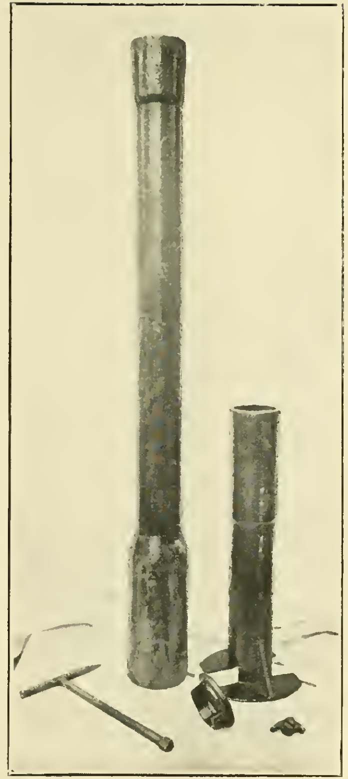

Fig. 2. — New Bedford Service Box.

Fig. 3. — Stacy Service Box.

found by many people that a heavy steam roller, or any heavy truck, passing over such boxes will invariably break them; and so we have improved ours by leaving off the thread and making the sliding joint of a plain, smooth, straight pipe, of wrought iron instead of cast iron. Another point is that many service boxes are made very light, — thinner castings are used for that purpose than are the castings for almost any other purpose that the water-works man comes in contact with; and so we have put in a little more cast iron, which we think is an improvement. Some of the other features may be imaginary advantages, — I can't say about that; but we have been told by a great many people that the corporation cock is apt to get misplaced, either to tilt sidewise or else to work endwise through the opening of the lower section. So this box is provided with a base or foot-piece, which is made so it will hold most of the corporation cocks in use to-day, and prevent them from rotating or moving endwise. This insures the cock being in line with the wrench. If the top section rises four or five inches in the winter time, you can hammer it down in the spring. The capscrew is provided with a five-sided head, and cannot be turned by an ordinary wrench. These are the special features, but I would repeat that the sliding parts are made of wrought iron instead of cast iron.

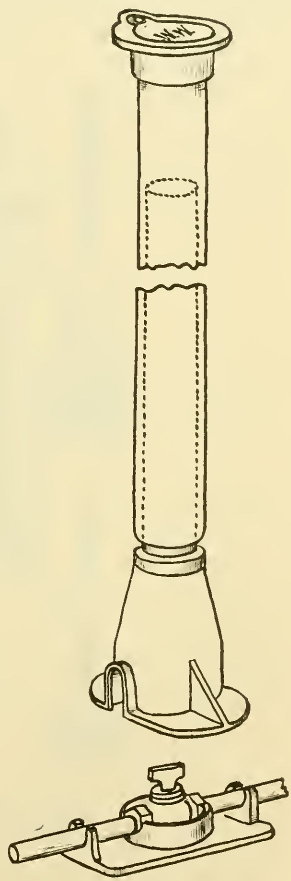

FIG. 2. — STACY SERVICE BOX.

A MEMBER. I should like to ask how much this costs?

MR. CONNET. The list price is two dollars.

THE MEMBER. Oh, I mean the net price.

MR. CONNET. We have to size a man up before we determine that. We will make a special discount of twenty per cent. to you, however.

The President. We would like to hear from Mr. Holden.

Mr. Horace G. Holden.* We use a box of our own design, which is in some respects like the Stacy box. That is, we have a casting at the bottom, which fits over the service pipe, and into this

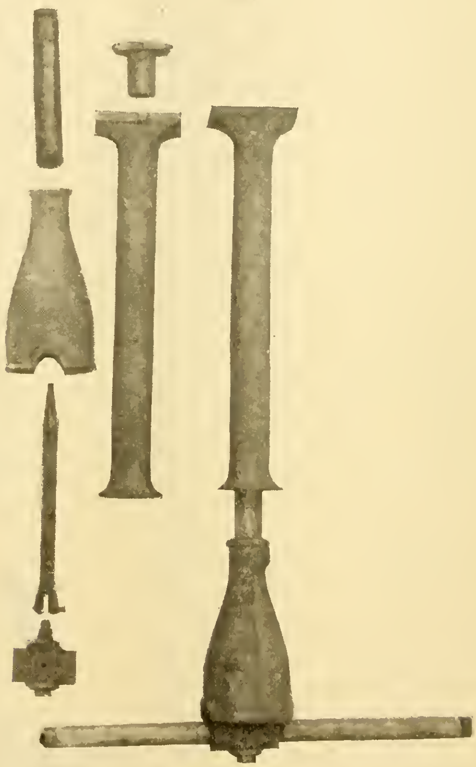

Fig. 3. — Service Box made by the Pennichuck Water Works, Nashua, N. H.

casting is fitted a one-inch plain iron pipe about four feet long (Fig. 3). Over this pipe is a telescopic casing eighteen inches long, which we can raise or lower to conform to the grade of the street. We have a rod which straddles the cock, and comes up into this pipe about half-way. We use a wrench made from a half-inch rod split at one end,

* Superintendent, Pennichuck Water Works Company, Nashua, N. H.

which we can drop right down and be sure of striking the extension rod. You can open or shut the cock without any trouble, and are always sure to hit right upon it. The material costs us about sixty cents for each box. We don't count the labor of making the boxes as anything, because the men put them together on rainy days, when they have nothing else to do. We seldom have any trouble with the boxes. The frost will occasionally raise them a little, and in the spring of the year a man has to go round with a maul and drive some of them down; and in case the earth has got over any of them so they are covered, it is very easy to raise them up a little to conform to the grade.

THE PRESIDENT. Mr. Bancroft, can you give us any light on the subject of service boxes?

MR. LEWIS M. BANCROFT.* Mr. President, I don't know as I can give you any light. We use the Bingham & Taylor box, and we have one expensive one like Mr. Martin's. They will come up sometimes in the spring, and people will find them when we don't want them to.

THE PRESIDENT. Those of us who went to Syracuse probably observed, in passing about the city, service boxes sticking up in the sidewalk anywhere from one to two or three, and I think in a few cases as much as six inches. I know I made an inquiry as to whether there was n't any fault found at that, and I was told no, that it did n't make any particular difference; people did n't seem to care much about it. But I find that in New England we have got to have them flush with the sidewalk, or else there will be trouble.

I would like to ask Mr. Tower, of Cohasset, for his opinion.

MR. D. N. TOWER.† Mr. President, I have always used the Bingham & Taylor box, and I have had the same trouble you spoke of from their being thrown up by the frost. We used to use a 93 E box, which could be extended to three and one-half or four feet, but now we buy a size larger, a 93 B box, which opens a foot longer; and before setting the box we take a chisel and cut the thread off the lower section. That makes a regular telescopic box of it and prevents its being thrown up, and I like it very much. I have n't heard of anybody else doing that, and I thought it might be something new.

MR. CONNET. I have been told by the superintendent at Burling-

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*Superintendent, Reading (Mass.) Water Works.

†Superintendent, Cohasset Water Company.

ton, Vt., that they do the same thing there that Mr. Tower does, — chip off the thread.

Mr. George E. Winslow.* I cannot speak from present experience, Mr. President, but I can from the past. We used to use the Bingham & Taylor box, and before that, they used a cast-iron riser and a cast-iron sliding part at the top. The cover was an ordinary plug which could be kicked off or picked up very easily. If it was put flush it left the joint about an inch below the sidewalk, and the children would pick the covers off and fill the boxes with stones and gravel and sand, which caused us great inconvenience; so we adopted the Bingham & Taylor box and substituted them wherever we were obliged to remove the old ones. The Bingham & Taylor boxes have worked very well in Waltham, for most of the soil there is sandy or dry gravel, and it is very seldom that one of the boxes is raised by the frost. The feature of it which permits of its being adjusted to any height I think is very valuable. But in some parts of the city the soil is clayey or marly, in some cases, and loamy, and in such places the frost would raise the tops sometimes five or six inches above the surface; and there the Bingham & Taylor box did n't work well. The first season we could go along with an ordinary wooden tamper and tamp them down, but the next season we could n't do it. So after that I used to cut off the thread, as has been spoken of, — that is, on the riser part, — and put the top part over; and then if it was raised by the frost we could tamp it down easily. The Bingham & Taylor box is really the one that I like better than any other we tried.

The President. There is another trouble with the Bingham & Taylor box that I have found, especially in streets that are not curbed. That is, if a team drives along and strikes the edge of the cover, it either breaks the first piece or else breaks the nut off in the casting; and a box that has the cover clamped in the center never has that trouble.

I will call on Mr. Thomas, of Lowell.

Mr. Robert J. Thomas.† Mr. President, the box I use (see Fig. 4) is a plain telescopic box of wrought-iron tubing. On the bottom is a casting which fits our sidewalk cocks. We make our own sidewalk cocks and make them so this casting fits right on. We very rarely have any trouble in getting the wrench on the cock, and there is no chance for any dirt to get in around the handle of the cock, which

* Waltham, Mass. † Superintendent, Lowell Water Works.

is tapered so that the wrench readily strikes the key. On the top we have another casting with a plug in it, which is also fastened so it requires a big wrench to unfasten the plug. The advantage which we claim for this box, which is made in Lowell, is that, being of wrought-iron tubing, it is hard to break. The Bingham & Taylor box is easily broken, and the other boxes which are made of cast iron have to be handled carefully or else they will break. But you can put ours in the ground anywhere and they won't break; and, making our own cocks as we do, it is an advantage to have them made so that this casting fits very snugly upon the cock. The box has a rounded top.

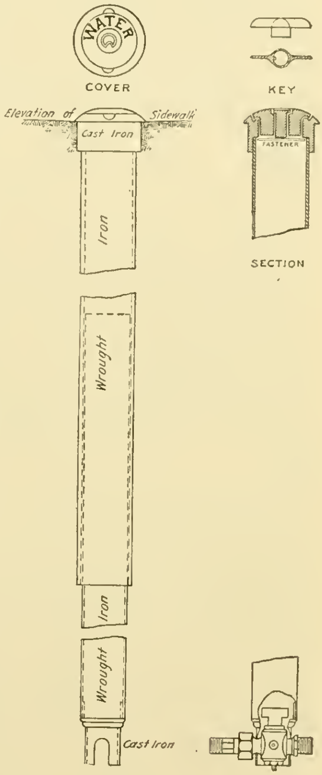

Fig. 4. — Lowell Service Box.

I am surprised that in Somerville, that being a temperance city, they should have any trouble in having to settle for damages to people from tumbling over the boxes. We never had a case of that kind in Lowell, — and we have license there, too. We don't have to tie a brass wire to the top to keep it from running off. We used to use a box with a plug in the top of it, and frequently we would find the plug was gone, that children had picked it up and carried it away.

I think the Stacy box is a good box, and if ours was n't made in Lowell I should favor the Stacy box, for I think it is the best box that I have seen on the market. As to the boxes in Syracuse, I was there at the time to which the President refers, but I did n't see any of them sticking up from the ground, and I don't see what was the matter with the President that he should have seen them.

The President. I should like to know what they use in Natick.

Mr. George W. Travis.* We use about the same box as Mr.

*Superintendent, Natick Water Works.

Walker has described, of the telescopic pattern, and it works very nicely, except, of course, we have some trouble from the frost lifting it, but it is an easy matter to drive it down again.

THE PRESIDENT. There seems to be a good deal of difference of opinion, as I have heard it expressed, among superintendents, in regard to the use of the extension rod, — whether the rod is useful or not. I have heard a good many say that it is apt to rust off, the pin is liable to get out of the stop-and-waste, and cause trouble that way; but I have used a rod for ten years and have never found any difficulty in that direction. I should like to hear from Quincy in regard to their service boxes.

MR. J. F. GLEASON.* We have used about all the boxes that are made. We have used the Taunton box, we have used the Bingham & Taylor box, we have used the M. J. Drummond box, and we now use the Coffin box, and I think this gives the best satisfaction of anything we have had. We have had a good deal of trouble with the Bingham & Taylor box. My idea of a service box would be one with a funnel-shaped top with the big end down into the ground. I think that would prevent it from being thrown by the frost.

THE PRESIDENT. Has Mr. Gow, of Medford, anything to say about service boxes?

MR. FREDERICK W. GOW.† We use the same box that Mr. Merrill uses, and, as he has said, it is not by any means an ideal box. Speaking of the bevel on the cover, I would say that it is n't safe to bank too much on that. The bevel on our box runs from five-eighths inch in the center to nothing at the edge, and we had a box which was flush on the side, which would leave the center of the cover up five eighths of an inch, and the city solicitor told me the other day he thought he could settle the case for three hundred dollars.

THE PRESIDENT. I believe there is hardly a water department in New England but that has had some experience in that line. If any one falls anywhere in the vicinity of a service box, the box is always blamed for it.

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* Foreman of Construction, Quincy Water Works.

† Superintendent, Medford Water Works.

ON THE RISE AND PROGRESS OF WATER-SUPPLY SANITATION IN THE NINETEENTH CENTURY.

BY WILLIAM T. SEDGWICK, PROFESSOR OF BIOLOGY IN THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

[*Presented February 13, 1901.*]

At a time when men of art, science, and literature are recalling the accomplishments of a century of wonderful activity and progress, it is fitting that the New England Water Works Association should also pause for a moment and review at least one aspect of the advancement which has been made within the century in its own peculiar field.

Few sanitarians even realize how recent are our modern ideas of water-supply sanitation. The clear recognition of water as a vehicle of infectious disease dates no further back than fifty years, and our methods of water purification so far at least as these may be called scientific and not purely empirical may be said to have grown up since 1886. There can be no doubt that epidemics due to infected water supplies had frequently decimated the human race during the long roll of the centuries that preceded the nineteenth, and yet mankind had continued in almost complete ignorance of its imminent danger from this source. If we ask how it happened to be left for the nineteenth century to teach us the great sanitary lesson that water is one of the most dangerous vehicles of infection, we shall probably find the answer in the fact that it is only in this century that careful scientific investigation of the natural history of disease has ever reached a high level. Modern sanitarians have been more fortunate than their predecessors simply because they have been more scientific.

At the beginning of the nineteenth century there was no such thing as water-supply sanitation. There were water supplies in abundance as there had been water supplies from time immemorial, but sanitation was something as yet hardly begun, and sanitation as applied to water supplies did not arrive until long after it had come in certain other directions. The occurrence of lead in drinking-water, for example, had long been known, and lead-poisoning was a subject

upon which a certain amount of knowledge had been collected, yet one of the most notable epidemics of lead-poisoning in a water supply occurred in the nineteenth century and was not only carefully studied, but happened to be so connected with royalty as to have attracted universal attention. As this case, though often referred to, is seldom cited in such a way as to be instructive to the modern sanitarian, I may venture to refer to it in some detail.

LEAD-POISONING IN THE FAMILY OF LOUIS-PHILIPPE.

Louis-Philippe and his family established themselves, after his abdication in 1848, on an estate in England known as Claremont; and although for some thirty years the water supply of the palace of Claremont had been drawn from a spring through lead pipes it had never been suspected of causing any trouble. After the arrival of the French royal family, however, lead-poisoning appeared in a very serious form among many of the inmates, and the case naturally attracted wide attention. A report upon it was made by Dr. H. Gueneau De Mussy, a distinguished French physician who attended the family, and may be found in the *Dublin Quarterly Journal of Medical Science, Vol. VII, for 1849.*

After having given a careful clinical account of the Claremont cases of lead-poisoning, of which there were thirteen out of thirty-eight persons in or about the palace, and after remarking that "the malady has shown no respect for condition and attacked indiscriminately servants, aides-de-camp, and princes, and did not spare even the most august and pious of victims," Dr. Gueneau De Mussy proceeds to describe the water supply of the palace as follows: —

"The spring that furnishes the palace of Claremont with water issues from a sand-bed at about two miles distance. It was chosen for its uncommon purity from among a great many others in its vicinity and the water was, thirty-three years ago, conducted to the palace through leaden pipes. In the present day some other metal would, perhaps, have been selected, for experience has taught us that pure water, and especially distilled water, acts rapidly on lead when it comes in contact with it. . . .

"The water of the palace of Claremont had been for many years employed by its inhabitants without any bad result; how was it, then, that this water, till now harmless, had become suddenly a violent poison? This is what has puzzled me and everybody else; and although I looked for its cause with the greatest attention, I could

discover only a single alteration, apparently of little importance, lately made in the transmission of the water.

"Until about eleven months ago, leaden pipes used to take up the water from a large natural cistern near its source. When the present occupants of the palace came to live in it, they wished to preserve this natural cistern from the vegetable and animal detritus that usually fell in it. For this purpose an iron cylinder of six feet diameter and twenty feet high was constructed and sunk into the ground fifteen feet deep. The water swelled up within, and a leaden pipe was attached to it with a funnel-like mouth projecting by a few inches in the inside of the cylinder, which was closed at the top by an iron cover with several holes in it to allow the air to make the requisite pressure on the surface of the water. You may discover what has been the influence of this change; for myself I think it has been the origin of all the evil. The datum is certain, but I have only hypothesis to offer as to the chemical reaction of the water. . . .

"The water of the iron cylinder did not contain any lead; that of the pipes contained some and that of the cistern [the leaden cistern in the palace in which the water naturally stood for some time] contained much more of it. . . .

"Professor Hoffman has ascertained the quantity of metallic lead in the water and has found that it amounted to a grain per gallon, an enormous quantity when we consider that the poisoned water was used in all culinary and table purposes, and, previously to the discovery of its deleterious character, even in the preparation of tisans and lavements."

This is not only one of the most famous, but also one of the most impressive cases on record, touching the conveyance of lead by drinking-water. From our present point of view it seems reasonable to suppose that the change from an open "cistern," in which the water was probably well aerated, to a closed iron cylinder with only a few holes in the cover, was sufficient to cause the retention of enough free carbonic acid to explain the result. I hardly need refer to the recent experience of the city of Lowell, in which a public water supply rich in free carbonic acid proved to be a dangerous solvent of lead.

PURE WATER SUPPLIES AS VEHICLES OF POISONOUS METALS.

In connection with water as a vehicle of lead ought always to be mentioned Professoı Drown's discovery of the possibility of the

similar conveyance of copper by water supplies charged with free carbonic acid. The case was that of a prominent family having a summer home near the Blue Hills in Milton, Mass. Members of the family were found to be suffering from obscure poisoning of some sort which was finally proved to be due to copper. Professor Drown discovered that the water supply of the house was derived from a spring on an uninhabited hillside, and that the water, while otherwise above reproach, was so rich in free carbonic acid that it readily attacked copper. Within the house, brass instead of lead connections had been used, and the result was a slow and insidious poisoning of the family by means of copper conveyed by water. The results of Professor Drown's studies in connection with this case, and the more recent epidemics of lead-poisoning in Lowell, Mass., and elsewhere, traced by the chemists of the State Board of Health to the action upon lead pipes of a relatively pure groundwater containing free carbonic acid in excess, constitute a distinct and important advancement within the century in our positive knowledge of the dangers of water supplies as possible vehicles of poisonous metals or solutions of their salts. (*See Thirty-First Annual Report, State Board of Health of Massachusetts, 1899, pp. xxxi and 26.*)

THE TARDY RECOGNITION OF WATER AS A VEHICLE OF INFECTION.

The fact that a water supply may under certain circumstances become a vehicle of the germs of infectious disease is a discovery of the latter half of the nineteenth century. "That a certain connection exists between the use of impure water and the spread of pestilential disease is a circumstance that has been observed from the earliest times," but this observation, being only of a loose and general character, had not prevented the almost universal use of more or less impure water supplies for domestic purposes even much later than 1850. The sanitary condition of the water supply of London during the cholera epidemic of 1854 will shortly be described. It was not very much better during the next great cholera outbreak, in 1866. Almost at the end of the century, in 1892, the cholera test proved conclusively that the water supply of Hamburg, one of the largest and most important commercial cities of Germany, was highly impure. The water supplies of Paris, Philadelphia, Washington, Chicago, St. Louis, Pittsburgh, and many smaller cities still remain more or less impure even at the end of the century. It will always be one of the sanitary paradoxes of the "wonderful century" that some of the most

progressive cities of the United States acting on the honest, intelligent, and expert advice of the ablest contemporary engineers, even as late as the seventies introduced water supplies derived from obviously polluted rivers or lakes and delivered, directly to the people, polluted water without previous purification of any kind. This was the case, for example, at Chicago, — where the water supply was originally derived from an intake distant only one mile from the lake-front and subject to pollution not only from sewers on that front but also at times from the discharges of the then very foul stream, the Chicago River; at Pittsburgh, — where the water of two highly polluted rivers was chosen as the source of supply; at Lowell and Lawrence, Mass., — which as late as 1872 turned without hesitation to the highly polluted Merrimac; at Burlington, Vt., — where in 1867 water began to be drawn from Lake Champlain at a point less than a mile from the outfall of the main sewer into the same lake; and at many other places.

QUIET WATER — NOT RUNNING WATER — PURIFIES ITSELF.

The reason for this practice, now so thoroughly discredited, was as is well known an undue reliance upon the so-called "self-purification of streams," a process which, though often real, is often also incomplete and untrustworthy. The idea prevalent in the greater part of the century that "running water purifies itself," while true enough up to a certain point and especially true so far as purification by dilution and by the displacement of dissolved gases is concerned, has in the last years of the century been shown to be either erroneous or to have little or no meaning so far as the direct oxidation of organic matter or the destruction of many living microbes which may be present in suspension are concerned. For these latter, on the contrary, it would probably be more correct to say that "quiet water purifies itself," since in such water microbes tend eventually to disappear, either dying from old age or inanition or settling to the bottom and being there detained.

SANITARY CONDITION OF THE LONDON WATER SUPPLY IN 1837.

It is universally recognized and admitted that the distinction of leadership in sanitary progress in the nineteenth century rightfully belongs to England. It is interesting, therefore, to inquire what progress in water-supply sanitation had been made in the English

metropolis in the first half of the century. The following report, made by a physician in 1837, throws some light on the subject: —

"In no part of France, Würtemburg, Bavaria, Bohemia, Prussia, Saxony, the Confederated States of Germany, Holland, and Belgium is there a city in which, as in London, the general mass of filth of every description created by a vast population is first allowed to enter the river which may happen to traverse that city and is then returned, diluted with the water of that river, to the houses of the inhabitants to be used either for domestic or culinary purposes. Although by avoiding the latter disgusting alternative, foreign cities are less free from unpleasant smells than London is, in this respect it may be truly said that foreigners smell the filth of their cities but do not swallow it, whereas London swallows it but seldom smells it." (*Report of A. B. Granville, M.D., to the Board of Directors of the Thames Improvement Company, January 2, 1837.*)

THE WATER SUPPLY OF LONDON IN 1854.

The sanitary — or unsanitary — condition of the London water supply even as late as 1854 is described as follows in an official report: —

"The sources from which every Metropolitan Company, without exception at present, derives its supply are more or less impure. . . . The most impure, on the south side of the river, is the Southwark and Vauxhall water, taken at Chelsea Reach. This last water contains the *débris* of food derived from the water-closets and sewers of the metropolis. It also contains living organisms which naturally belong to brackish waters, which proves that a certain amount of tidal sea-water is supplied to the inhabitants of the district. Between it and the water of the Thames . . . there is frequently only that amount of difference which would arise from mere subsidence. The water is nearly always more or less opalescent; . . . the complaints made of this water are almost universal. . . . Nearly all the shallow well and pump-waters were of a very impure description. . . . The baths and wash-houses have been supplied with water of so bad a quality that they have become greatly disused. . . . Dr. Hassall says in regard to the Southwark and Vauxhall water that its use ought not to be permitted an hour longer than is absolutely indispensable. In several localities there is no water supply at all, the people either buying from water-carts, or taking water from the Thames, the Wandle, or even from ditches. . . . In Chelsea there are still a

great many places where the people are dependent upon bad wells or on the river." (*Report of Dr. Sutherland, Medical Inspector, to the General Board of Health, on Epidemic Cholera in the Metropolis in 1854.*)

DIFFERENCES OF OPINION CONCERNING THE RÔLE PLAYED BY IMPURE WATER IN THE CAUSATION OF DISEASE.

Such was in 1854 the sanitary condition of the public water supply of the metropolis of England, which country has been not only the pioneer but also the leader in sanitation in the century under consideration. It was at this time (1855) even actually doubted, by good authorities, that water is a vehicle of infectious disease, for it was held by many that, even when polluted, it was only a "predisposing," not a direct and sufficient, cause of disease. Dr. Sutherland, for example, in the report already referred to, while beginning his paper with the dictum quoted above, "that a certain connection exists between the use of impure water and the spread of pestilential disease is a circumstance that has been observed from the earliest times," remarks also that "there is a difference of opinion on the part which impure water plays in the phenomena," and continues: "It is believed by some that the water which induces cholera contains the specific poison of cholera in it, probably derived from the evacuations of cholera patients, while others believe that there is no sufficient evidence of this . . . and consider . . . that water containing putrescent organic matter acts as a very powerful predisposing cause . . . but not as a specific poison."

POPULAR PREJUDICE AGAINST PUBLIC WATER SUPPLIES.

In view of the uncertain attitude of experts towards water as a vehicle of infectious disease, and in view of the plainly unwholesome character of such public water supplies as that of London, it is not surprising to find some popular opposition to the introduction or extension of public water supplies. An amusing instance of such opposition was the following: "The sanitary works of Penrith were begun in 1853 and were completed in 1856; but recently, in 1862–63, they have been extended. The water supply was shortly found to be inadequate to the wants of the town, and much care was given to discover the cause of it. The higher districts of the town were especially ill supplied, and the want of pressure was supposed to be due to leakage. It was not until an extension of the water works,

at much expense, in 1862, that the cause of this inadequate supply was discovered, and then it proved to have been in existence since the beginning of the works in 1853. It was found that some logical and consistent opponent of the sanitary measures that were then being adopted had previously inserted into one of the water mains a five-foot pole and fixed it there with wedges. By degrees this pole had got accumulations round it and the water supply had become scantier and scantier." (*Dr. Buchanan, Water Supply of Penrith, Ninth Annual Report, Medical Officer of the Privy Council, pp. 173, 174. London, 1867.*) The fear of lead-poisoning from public supplies was apparently so great among some persons in Boston in 1849 (perhaps because of the contemporary Claremont epidemic) that some householders who desired, yet dreaded, to take the new Cochituate supply just then being introduced, employed glass-lined pipes for house connections.

ASIATIC CHOLERA IN LONDON IN 1854 AND THE LESSONS OF THE BROAD-STREET WELL.

Enough has now been said to show not only that water-supply sanitation had no existence in the first half of the nineteenth century, but also that experts as well as the people at large were still in doubt and perplexity as to the part played by polluted water in the propagation of infectious disease. Before water-supply sanitation could be seriously considered and developed, the necessity and the reasons for it had to become more clear. And after the middle of the century both the necessity and the reasons soon became apparent. Even as Dr. Sutherland was writing his report, there appeared a brief paper on a curious concentration of cholera cases about a polluted well in Broad Street, London, which to many of those most competent to judge seemed to establish beyond peradventure the theory that a public water supply might be not only the predisposing cause but the direct and ready vehicle of the specific poison of Asiatic cholera.

London was still abundantly supplied with wells and pumps in or near the public streets when the cholera again appeared in the city in 1853. One of the principal parishes of the city, that of St. James, Westminster, had suffered somewhat during the cholera epidemics of 1832 and 1848 and now suffered once more in 1853 but on the whole rather less, relatively, than the rest of London. In 1854, however, the reverse was the case, the Cholera Inquiry Committee

having estimated that "in this year the fatal attacks in St. James Parish were probably not less than 700" on an area of 164 acres and among a population of about 37 000. Careful study showed further that a very large part of this mortality was localized within a particular district of the parish, the remaining districts showing no special excess of cholera-mortality above the rest of London. Attempts were made to find a cause for this local excess in peculiar geographical and atmospheric conditions; in "a previous long-continued absence of rain"; in "a high state of the temperature both of the air and of the Thames"; in "an unusual stagnation of the lower strata of the atmosphere highly favorable to its acquisition of impurity," and in the combination of these and other "factors"; but the Inquiry Committee perceived that "the resulting mortality was so disproportioned to that in the rest of the metropolis and more particularly to that in the immediately surrounding districts that we must seek more narrowly and locally for some peculiar conditions which may help to explain this serious visitation."

Fortunately, at the very beginning of the outbreak of cholera in the district, Dr. John Snow, with a novel and highly commendable curiosity, had taken the trouble to learn the number and exact location of the fatal cases, as is stated in his own report to the Cholera Inquiry Committee: —

"I requested permission on the 5th of September to take a list at the General Register office of the deaths from cholera . . . and I made inquiry in detail respecting the eighty-three deaths registered. . . . On proceeding to the spot, I found that nearly all had taken place within a short distance of the pump in Broad Street."

This is not the place to give a detailed account of the remarkable outbreak which Dr. Snow studied with so much modesty, care, ability, and success. It suffices for our present purpose to state that further investigations by Dr. Snow and by others seemed at the time to prove, and are now universally admitted to have established, the fact that a polluted and infected drinking-water was in this case not merely a predisposing factor of disease but the effective vehicle of the poison peculiar to the disease, which poison actually produced the excess of Asiatic cholera plainly visible in the immediate vicinity of the well on Broad Street from which the water containing the poison was drawn. Close study revealed not only the fact that all, or very nearly all, of those in the vicinity who suffered from cholera had used the water from the pump in question, while those who escaped

had not used it, but also some very remarkable instances of cholera among persons living at a distance who had by accident or design drunk of the water from this well, and afterwards had the disease, although no cholera cases appeared among their neighbors for miles around. Between August 19 and September 30, 1854, no fewer than 616 deaths from Asiatic cholera are recorded by Dr. Snow as having occurred in the vicinity of the Broad-street pump. In Broad Street alone, containing only 49 houses and but 896 inhabitants, there were 90 deaths from cholera, as was learned by a careful house-to-house inquiry conducted by the Rev. Mr. Whitehead. A further investigation by Mr. J. York, a surveyor and the secretary to the Inquiry Committee, showed that the well which was incriminated was situated only three feet from a cesspool used by the family at No. 40 Broad Street, and that this cesspool had for some time been overflowing and leaking directly into the well. Also, that certain cases of diarrhœa, probably choleraic in character, had occurred in the house No. 40, just before the terrible outbreak of cholera among the users of the water. (*Report on the Cholera Outbreak in the Parish of St. James, Westminster, during the Autumn of 1854. London, J. Churchill, 1855.*)

DIFFERENCE OF OPINION AMONG EXPERTS AS TO THE CAUSE OF THE BROAD-STREET EPIDEMIC.

To show how little agreement existed in 1854 even among experts as to the probability that drinking-water could serve as a ready vehicle of disease, it is worthy of notice that a Committee for Scientific Inquiries in relation to the cholera-epidemic of that year, composed of five eminent persons, of whom two, Dr. (now Sir) John Simon and Dr. William Farr, were among the most competent sanitary experts of the time, reported concerning this epidemic under date of July 14, 1855, to the President of the General Board of Health, as follows: —

"That such local uncleanliness prevailed most intensely throughout the suffering districts is evident from the reported results of house-to-house visitation. The exterior atmosphere was offensive with effluvia from ill-conditioned sewers; the houses were almost universally affected in the same manner, partly from the same source, partly from their own extreme defects of drainage and cleanliness, partly from unregulated slaughtering and other offensive trades; the

inhabitants were overcrowded, perhaps to the greatest degree known even in London; and the general architecture of the locality was such as to render it almost insusceptible of ventilation. . . .

"Why, however, this district should have suffered in marked disproportion to many other districts, hardly, if at all, superior in their sanitary arrangements; or why, generally, it should be the tendency of cholera in its visitation to select particular foci for extreme outbreaks, instead of diffusing itself more equally over all ill-conditioned districts, is a difficulty which hitherto we have no scientific material to solve. . . .

"In explanation of the remarkable intensity of this outbreak within very definite limits, it has been suggested by Dr. Snow that the real cause of whatever was peculiar in the case lay in the general use of one particular well, situate at Broad Street in the middle of the district, and having (it was imagined) its waters contaminated with the rice-water evacuations of cholera patients.

"After careful inquiry, we see no reason to adopt this belief. We do not find it established that the water was contaminated in the manner alleged; nor is there before us any sufficient evidence to show whether inhabitants of the district, drinking from that well, suffered in proportion more than other inhabitants of the district who drank from other sources.

"There is mentioned, however, a remarkable instance in which it seems probable that the water of this well did really act as a vehicle of choleraic infection; but (assuming the absence of fallacy in the case) this probability might easily be admitted, without its therefrom resulting that infection depended on the specific material alleged. The water was undeniably impure with organic contamination; and we have already argued that if, at the times of epidemic invasion, there be operating in the air some influence which converts putrefiable impurities into a specific poison, the water of the locality, in proportion as it contains such impurities, would probably be liable to similar poisonous conversion. Thus, if the Broad Street pump did actually become a source of disease to persons dwelling at a distance, we believe that this may have depended on other organic impurities than those exclusively referred to, and may have arisen, not in its containing choleraic excrements, but simply in the fact of its impure waters having participated in the atmospheric infection of the district." (*Report of the Committee for Scientific Inquiries, etc., pp. 51 and 52. London, 1855.*)

ASIATIC CHOLERA IN A LONDON WATER SUPPLY IN 1866. RISE OF THE GERM THEORY OF DISEASE.

It is easy to perceive from a perusal of the foregoing statements that in 1855 the very basis of water-supply sanitation had yet to be laid even in that country which has been, during the nineteenth century, the acknowledged leader in both the theory and the practice of sanitation. The cholera epidemic of 1866, however, furnished a striking demonstration of the fact that a sewage-polluted water may become the effective vehicle of the actual poison of disease; for during this epidemic it was clearly established that the cholera was in excess within the precise limits of distribution of drinking-water by one of the Metropolitan Water Companies which, though supposed to be filtering its supply, did as a matter of fact distribute to its patrons unfiltered water which had apparently been infected with the excrements of cholera patients. (*See Report of J. N. Radcliffe, Ninth Annual Report, Medical Officer of the Privy Council, London, 1867; also Rivers Pollution Commissioners, Sixth Report, p. 144.*) There is good reason to believe, however, that the cause of this epidemic would likewise have been attributed by many to mysterious predisposing influences, such as atmospheric conditions, climatic changes, or other factors, had it not been for the circumstance that during the decade in which the epidemic occurred a new and helpful theory of the precise cause of infectious disease had sprung up in consequence of the epoch-making researches of a French mineralogist and chemist, then little known, but destined to become, shortly, one of the most famous workers in the annals of the nineteenth century; namely, Louis Pasteur, who had then recently established both the germ-theory of fermentation and the germ-theory of the diseases of wine and beer. Already it was more than suspected that the infectious diseases of man and the lower animals must likewise be due to living germs, and when the next serious epidemic which appeared to be due to a polluted water supply occurred, namely, the Lausen epidemic of typhoid fever in 1872, the germ-theory of infectious disease, though not yet fully established, had already won popular recognition and had become even among experts an accepted working hypothesis which had the great merit of furnishing a ready explanation for many of the obvious facts of epidemiology, and accordingly proved a powerful support for what was now called the "drinking-water theory" of infectious disease (*Trinkwasser Theorie*).

AN EPIDEMIC OF TYPHOID FEVER IN LAUSEN, SWITZERLAND, TRACED TO AN INFECTED PUBLIC WATER SUPPLY.

The epidemic in question may be said to have been the turning point in favor of the theory that impure drinking-water may be not only a predisposing cause, but the actual vehicle of the *materies morbi* of infectious disease, and, as might have been expected, the battle between the two camps was hotly contested. Now that the smoke of it has disappeared, it is easy to see that the victory belongs undoubtedly to those who held the *Trinkwasser Theorie*. The epidemic occurred in the little village of Lausen in the Canton of Basel in Switzerland in August, 1872. Lausen was a well-kept village of 90 houses and 780 inhabitants, and had never, so far as known, suffered from a typhoid epidemic. For many years it had not even had a single case of typhoid fever, and it had escaped cholera even when the surrounding country suffered from it. Suddenly, in August, 1872, an outbreak of typhoid fever occurred, affecting a large part of the entire population. A short distance south of Lausen was a little valley, the Fürlerthal, separated from Lausen by a hill, the Stockhalden, and in this valley upon an isolated farm on June 19, a peasant who had recently been away from home, fell ill with a very severe case of typhoid fever which he had apparently contracted during his absence. In the next two months there occurred three other cases in the neighborhood, — a girl, and the son and the wife of the peasant.

No one in Lausen knew anything of these cases in the remote and lonely valley, when suddenly, on August 7, ten cases of typhoid fever appeared in Lausen, and by the end of nine days, fifty-seven cases. The number rose in the first four weeks to more than one hundred, and by the end of the epidemic in October to about one hundred and thirty, or seventeen per cent. of the population. Besides these, fourteen children who had spent their summer vacation in Lausen came down with the disease in Basel. The fever was distributed quite evenly throughout the town, with the exception of certain houses which derived their water from their own wells and not from the public water supply. Attention was thus fixed upon the latter which was obtained from a well at the foot of the Stockhalden hill on the Lausen side. The well was walled up, covered, and apparently protected, and from it the water was conducted to the village, where it was distributed by several public fountains. Only six

houses used their own wells, and in them there was not a single case of typhoid fever, while in almost all the other houses of the village, which depended upon the public supply, cases of the disease existed. Attention was directed to the water supply as the source of the typhoid poison, very largely because no other source could well be imagined. A distribution of the disease from the farm through the air was hardly conceivable because houses in the Fürlerthal, although lying upon the same plateau and naturally more accessible through the atmosphere, remained free from the disease, which fact seemed to prove that the infected farmhouse could not have communicated the disease to Lausen either through the ground-water or through the air.

THE FÜRLER BROOK AND THE LAUSEN WELL.

In order, however, to clinch the evidence that the well had been infected, it became desirable to show some source from which an infection, so unusual and remarkable, could have come, and precisely how it happened. There had long been a belief that the Lausen well was fed by and had a subterranean connection with a brook (the Fürler brook) in the neighboring Fürlerthal; and since this brook ran near the peasant's house and was known to have been freely polluted by the excreta of the typhoid-fever patients, absolute proofs of the connection between the well of Lausen and the Fürler brook could not fail to be highly suggestive and important. Fortunately such proofs were not far to seek. Some ten years before, observations had been made which had showed an intimate connection between the brook and the well. At that time without any known reason, there had suddenly appeared near the brook in the Fürler valley below the hamlet, a hole about eight feet deep and three feet in diameter, at the bottom of which a considerable quantity of clear water was flowing. As an experiment, the water of the little Fürler brook was at that time turned into this hole, with the result that it all flowed away underground and disappeared. An hour or two later the public fountains of Lausen which, on account of the dry weather prevailing at the time, were barely running began flowing abundantly. The water from them which was at first turbid, later became clear; and they continued to flow freely until the Fürler brook was returned to its original bed and the hole was filled up. But every year afterwards whenever the meadows below the site of the hole were irrigated or overflowed by the waters of the brook,

the Lausen fountains soon began to flow more freely. In the epidemic year (1872) the meadows had been overflowed as usual from the middle to the end of July, which was the very time when the brook had been infected by the excrements of the typhoid patients. The water supply of Lausen had increased as usual, had been turbid at the beginning and had had a disagreeable taste. About three weeks after the beginning of the irrigation of the Fürler meadows fever broke out, suddenly and violently, in Lausen.

EXPERIMENTAL DEMONSTRATION OF CONNECTION BETWEEN THE FÜRLER BROOK AND THE LAUSEN WELL.

In order to make matters, if possible, more certain, the following experiments were made, but unfortunately not until the end of August when the water of the Lausen supply had again become clear. The hole which had appeared ten years earlier, and had afterwards been filled up, was dug out and the little brook was once more led into it. Three hours later the Lausen fountains were yielding double their usual volume. A quantity of brine containing about eighteen hundred pounds of common salt was now poured into the brook as it entered the hole, whereupon there appeared very soon in the Lausen water, first a small, later a considerable, and finally a very strong, reaction for chlorine, while the total solids increased to an amount three times as great as before the brine was added. In another experiment, five thousand pounds of flour (*Mehl*), finely ground, were likewise added to the brook as it disappeared in the hole; but this time there was no increase of the total solids, nor were any starch-grains detected in the Lausen water. It was naturally concluded from these experiments that while the water of the brook undoubtedly passed through to Lausen and carried with it salts in solution, it also underwent a filtration which forbade the passage of suspended matters as large as starch-grains.

Unfortunately, this was before pure cultures of bacteria were known and no experiments were made with suspended matters as small as bacteria. Dr. Hägler, from whose report the foregoing facts are taken, was careful, however, to state that "it is not denied that small organized particles, such as typhoid fever germs, may nevertheless have been able to find a passage." As a matter of fact, Dr. Hägler's minute account does to-day give us some indication that such germs might easily have passed from the brook to Lausen, for the turbidity of which he repeatedly speaks is evidence of the passage

of particles probably as small as, and possibly smaller than, the germs of typhoid fever. (*Typhus und Trinkwasser*, *Vierteljahrschrift für öffentliche Gesundheitspflege*, *VI*, *154; also Sixth Report*, *Rivers Pollution Commissioners of 1868. London*, *1874.*)

EFFECT OF THE LAUSEN EPIDEMIC UPON CURRENT THEORIES.

This epidemic formed the subject of lengthy debates and discussions between the defenders of the "Trinkwasser" theory, the "Grundwasser" theory, and the "Pythogenic" theory. The biologists naturally took sides with the first of these; the second was upheld by Pettenkofer and his powerful school; and the third by the followers of Murchison, the original exponent of the theory that filth is in itself somehow capable of generating specific diseases. This last theory had already begun to decline, and after the publication of Dr. William Budd's famous work on typhoid fever in 1873, found few supporters.

The "Ground-water" theory of typhoid fever was based upon the fact that in some cases typhoid fever has undoubtedly been more abundant when the level of the ground water is low and less frequent when that level is high. It was fortunate in its principal exponent and defender, Professor Pettenkofer, of Munich, — who has just expired only three days ago, almost exactly with the century in which he was so prominent a figure; but it was based upon an assumption which though often true is not invariably true, while the facts for which it accounted were susceptible of other explanations far more intelligible and satisfactory. Moreover, it utterly failed to account for outbreaks like that in Lausen. The latter, on the other hand, was perfectly simple on the assumption that the germs of disease had passed from the patients in the valley to the water-takers in Lausen; while the fact that they had for years been drinking from a polluted but uninfected brook completely disproved the pythogenic theory. In brief, when some years later the noise of the controversy had died away, it was gradually perceived that the opponents of the drinking-water theory had been completely routed, and that this theory and its analogue, the germ-theory of disease, had won a great and decisive victory.

INVESTIGATIONS BY THE RIVERS-POLLUTION COMMISSION OF 1868.

Meantime English sanitarians had not been idle. The pollution of the rivers of England by sewage and manufacturing wastes had

become an evil so serious that a Royal Commission was appointed in 1868 to investigate and report upon the subject, and their results constitute one of the most important contributions to the progress of water-supply sanitation within the century. The Reports of the Rivers Pollution Commission are a great mine of sanitary information and a magnificent monument to sanitary research. Among many other subjects, the commissioners were, fortunately, especially instructed to investigate the whole question of the water supply of England and Scotland, and we owe to their studies the first proofs that the self-purification of streams is incomplete and untrustworthy, and the first sound evidence and recognition of the sanitary value of filtration in the purification of polluted waters. I have already touched briefly upon the former topic, and need not deal with it further here. The latter, however, requires more extended treatment, as this period marks the scientific beginning of those remedial measures for polluted water supplies with which we are so much concerned at the end of the century.

THE BEGINNINGS OF WATER-SUPPLY PURIFICATION BY MEANS OF FILTRATION THROUGH SAND.

One of the earliest modern movements, if not the earliest, looking toward the purification of a public water supply, occurred in London in 1828, when a Royal Commission discussed the improvement of the quality of the water supply of London by means of filtration. The water companies, stimulated by the Report of the Commission, began to experiment and soon "found that when the water was allowed to filter downwards through a porous bed of sand, held up in its place by underlying layers of coarse gravel, the dirt did not penetrate into its mass but was stopped at the upper surface, so that the whole cleaning operation necessary was to scrape this surface off to a slight thickness, and when it had become too much diminished, to put fresh sand on. The plan of filtration thus matured was at once carried into practice. The first large filter of one acre area was set to work by the Chelsea Company in 1829. It was found to work well, and the principle has since been universally adopted." (*Report of the Royal Commissioners of 1866–1867 on Water Supply, p. xliii. London, 1869.*)

By an act of Parliament (15 and 16 Victoria, Cap. 84) which received the royal assent July 1, 1852, it was ordered that all water for domestic use in the metropolis should, from and after Decem-

ber 31, 1855, be "effectually filtered," unless it were pumped from wells.

There is no lack of evidence, however, that the filtration was very imperfect not only earlier, in 1850, but also in 1854 and even as late as 1874. Dr. Hassall, after studying microscopically the London water supply, writes in 1850: "The importance of filtration it is almost impossible to overestimate. . . . The method of filtration, to be successful even to a limited extent, must be very different from that pursued by the Metropolitan Companies; for . . . the waters which they supply, after having undergone the process as conducted by them, still contain much solid organic matter, living, dead, and decomposing, and often of considerable size. . . ." (*A. H. Hassall, M.D., A Microscopic Examination of the Water Supplied to the Inhabitants of London. London, 1850.*)

During the cholera epidemic of 1854, the water supply of London was carefully examined, and it is recorded that "the Lambeth water is comparatively a pure water, clear and bright. . . . This water is filtered, but the Southwark and Vauxhall water is not filtered. . . . The greatest amount of foreign matter existed in the water supplied by the Chelsea Company. . . . Next to the Chelsea water was found to be that of the Southwark and Vauxhall Company. . . ." (*Dr. Sutherland's Report, pp. 43, 44, l. c.*)

In 1866 the constitution of the Thames Conservancy Board was altered and its powers enlarged by an act (29 and 30 Victoria, Cap. 89) which made two important provisions for ensuring the purity of the water, namely: first, the surface of the water of the river was to be effectually scavenged; second, the admission of sewage or any other offensive or injurious matter into the Thames, or into any tributary of it within three miles of its junction with the Thames, was declared illegal and subject to heavy penalties. In 1868 a similar act was passed for the better conservation of the purity of the river Lee, another of the sources of water supply for London.

The processes of filtration appear to have been gradually improved, though by no means perfected, after 1854, and the cholera in London in 1866 served to show in the most striking manner the very great sanitary value of even shallow sand-filters. Unfortunately, the obvious lesson from this experience was not universally accepted probably because of the confusion of thought and opinion caused by the "pythogenic" theory, the "ground-water" theory, and the "predisposition" theory, all of these contending with

the "drinking-water" theory and the "germ" theory, then just beginning to be seriously considered. It is very interesting and instructive to observe that even the Rivers Pollution Commissioners, although they themselves show that both actual experience and chemical analyses prove in the clearest manner the great sanitary value of filtration in the purification of water supplies; and although in the body of their Sixth Report (1874) they draw from these facts the natural and logical conclusions; have, nevertheless, placed at the end of that section of their Report dealing with the subject a remarkable paragraph virtually rejecting their own conclusions and warning their readers against dependence on filtration as a sanitary safeguard. Moreover, their final "Conclusions and Recommendations," briefly summarized at the end of the volume, are so plainly unfavorable to filtration as to excite surprise to any one who has carefully read the evidence of its value which they themselves give in the body of their Report. The modern student of the subject will find it difficult to resist the suspicion that these final paragraphs were inspired and appended in consequence of a careful consideration by the commissioners of the Lausen epidemic in 1872. There is internal evidence of the probability of this hypothesis in the final paragraphs themselves and in the date of the Report, in addition to the well-known fact that the Lausen epidemic made everywhere a profound impression and was widely and even hotly discussed. One example of this peculiar attitude of the commissioners towards filtration may be cited: —

"The improvement of the quality of drinking-water by filtration has scarcely received so much attention as it deserves. . . . Whenever towns have the misfortune to be supplied with water from rivers polluted by sewage, efficient filtration should always be stringently insisted on. . . . We have already explained the frightful results which occurred in the east of London in the cholera epidemic of 1866 from probably not more than a single hour's suspension of filtration. . . ." (*Sixth Report, pp. 216, 218.*)

Per contra: "We desire it to be distinctly understood that although this purification . . . may reasonably be considered on theoretical grounds to be some safeguard against the propagation of epidemic diseases, there is not in the form of actual experience a tittle of trustworthy evidence to support such a view. On the contrary, the investigation of the epidemic of typhoid fever at Lausen, in Switzerland, proves that even very efficient filtration does not

prevent the propagation of that fever by water. . . ." (*Sixth Report, p. 221.*)

INFLUENCE OF BACTERIOLOGY UPON THE THEORY OF FILTRATION.

In brief, the conclusions of the Rivers Pollution Commissioners bore heavily against the sanitary efficiency of filtration, and served to strengthen the doubts of its value naturally raised by the phenomena of the Lausen epidemic. Facts tending to show the efficiency of filtration, such as those observed in the cholera epidemics of 1854 and 1856, were overlooked or disregarded and very little further progress was made in its study until the introduction of the novel methods of bacteriology rendered it possible and easy for Prof. P. F. Frankland to show, in 1886, a very high efficiency of the London filters in removing microbes from the waters of the Thames and the Lee. Similar results were obtained in America soon after for the Merrimac River at the Lawrence Experiment Station of the Massachusetts State Board of Health, and these were succeeded by an experiment upon the large scale in the installation of the municipal filter for the city of Lawrence, which was in turn followed by the reduction of an excessive death-rate from typhoid fever to one on a level corresponding to that of neighboring cities supplied with pure water.

These various results and the painful experience of Hamburg with cholera in 1892 resulting from the use of unfiltered water, while its next-door neighbor, Altona, enjoyed almost complete exemption, — though using water from the same river at a lower point and even more polluted, — simply because it first subjected the water to slow filtration; the favorable experiences with filtration of Berlin, Warsaw, and many other cities which have adopted filters of the English type; the remarkable experience of London itself, which since 1866 has continued to use largely for domestic purposes the well-filtered water of the rivers Thames and Lee, and yet has maintained a very low death-rate from infectious diseases; the lack of any fresh epidemic like that at Lausen to throw doubt on the efficiency of the process when wisely conducted; the general triumph of the germ-theory of infectious disease; and the rise of bacteriology, — all these and other favorable circumstances have naturally created the firm conviction that in filtration we have the best method yet discovered for purifying polluted waters so that they may be not only agreeable to look at but also safe and wholesome for drinking.

EXPERIMENTAL STUDIES ON THE THEORY AND PRACTICE OF FILTRATION.

The art of filtration has accordingly received in the last years of the century a great amount of attention. Its theory and practice have been carefully studied, — perhaps more carefully at the Lawrence Experiment Station of the Massachusetts State Board of Health than anywhere else, — and its applicability to various kinds of water under various conditions has received elaborate and extended investigation, especially at Louisville, Ky., and Cincinnati, Ohio, under the direction of Mr. George W. Fuller, and at Pittsburgh, Pa., by Mr. Allen Hazen. Under the advice and direction of Mr. Hazen, the city of Albany, N. Y., in 1899 constructed a municipal filter of the most modern type for the purification of the polluted Hudson River which, unfiltered, had long been at once the source of water supply and the cause of an excess of typhoid fever in Albany. This filter has already demonstrated its sanitary efficiency and will probably stand in the future as a representative example of the best practical achievement of the century in the purification of a polluted water supply by slow sand filtration.

PROTECTION OF THE PURITY OF WATER SUPPLIES AGAINST POLLUTION AT THEIR SOURCES.

Meantime we have been taught by other epidemics that a water supply undergoing alterations at its source and exposed to pollution by filthy workmen may be the effective vehicle of disease, — as happened in Caterham, England, in 1879, when the excretions of a single sick laborer, working in a new supply well in the chalk, apparently caused an extensive outbreak of typhoid fever among the users of the water; and we have learned by painful experience that excrements of typhoid-fever patients thrown upon a watershed may find their way into reservoirs or rivers and cause great epidemics like that at Plymouth, Pa., in 1885, and that at Lowell and Lawrence, Mass., in 1890–91.

PRESENT STATE OF THE SUBJECT.

The nineteeth century has thus witnessed the gradual rise of modern water-supply sanitation and considerable progress in its various branches. It is now agreed on all sides that impure water may be not merely a predisposing cause, but the actual vehicle, of infectious diseases such as Asiatic cholera and typhoid fever. The

"ground-water" theory and the "pythogenic" theory of typhoid fever have disappeared and the "germ" theory is the only one recognized to-day. One phase of this, now everywhere accepted, is the "drinking-water" theory which, under the head of "*Typhus und Trinkwasser*," was so much debated between 1865 and 1885.

Filtration through sand, proposed in 1828, begun in London in 1829, and required by law for river-waters in London after 1855, was at first slowly and empirically improved as an art, though its existence and sanitary value were repeatedly justified, especially in the cholera epidemic of 1866. It nevertheless passed under a cloud for a time, chiefly because of the phenomena of the Lausen epidemic of 1872, which seemed to show that even the most extensive filtration of an infected water supply was insufficient to remove the poison of the disease, and was only restored to its proper place in the confidence of experts after the lapse of time, the gradual accumulation of evidence in its favor, the powerful support of bacteriology, and especially after fresh and indubitable demonstrations of its efficiency and value, such as those afforded by the long experience of London, that of Altona in 1892, and that of Lawrence in 1893, etc.

The nineteenth century has also witnessed great progress in the general recognition of the absolute necessity of carefully protected watersheds, not only for the collection of surface waters which are to be used without filtration but also for those — such as the water of the Thames — which are to be both settled and filtered before their consumption. It has learned to recognize the fact that the so-called purification of polluted waters by "running" in rivers, and even by "storage" in small reservoirs, is often incomplete and untrustworthy, and recognition of this fact has led to great and enormously expensive undertakings such as the Metropolitan Water Works of Massachusetts and the Sanitary Drainage Canal of Chicago, both designed to secure not merely more abundant, but also purer, water supplies.

DISCUSSION.

Mr. George F. Chace.* It goes without saying, Mr. President, that we have all been very much interested in what Professor Sedgwick has said, and we are very much indebted to him. When he was speaking of lead pipes I could not help thinking of an old surgical story that I read some years ago. It seems a man had had an iron rod driven into his body somewhere, and when the surgeon

* Superintendent, Taunton Water Works.

was called to see what could be done for him, after he made his examination, he said: "If that iron is taken out of your body, in the position in which it is, you would bleed to death; if it stays there mortification will ensue, and that will kill you. Science has its limits and you may take your choice of deaths."

Now, I don't suppose there is a water-works man here who would not from a mechanical point of view prefer to use lead service pipes. It is a great deal less trouble in delivering water to consumers. There are a great many lead house pipes in some cities, and they find comparatively little difficulty with the water.

When our water works were built in Taunton, I think in almost every house there were iron service pipes, and these have continued to be used up to the present time almost exclusively. Our consumers got along very well up to 1894, when the Lakeville supply was put in. And the reason seemed to be, that the water which was used up to that time was not very pure in some respects. It had a considerable sediment, which formed a coating on the inside of the pipes, and which prevented very much corrosion; and unless that coating was disturbed, the service was very fair. But ever since 1894 I have been more or less abused by people who have complained of having rusty water in their houses and who have tried to lay it to the water department; and time and time again I have had occasion to disconnect the house pipe from the service pipe where it entered the cellar and show consumers that the water was clean from the main to the house, and that the trouble was in their own pipes; and I have told them again and again that so long as they continued to use plain iron pipes they would have rusty water, and that the cleaner and purer the water, the more it would rust the pipe. The remedy is to use some other kind of pipe, like tin-lined pipe, but that costs more. Much of the difficulty in remedying these sanitary troubles is that there are so many people in this world whose god is their pocketbook. If we are willing to pay the price, we can get along and lead rather healthy lives; but it will cost us something.

THE CAUSES OF RAINFALL.

BY PROF. W. M. DAVIS, HARVARD COLLEGE, CAMBRIDGE, MASS.

[An Informal Talk at the Meeting of February 13, 1901.]

Mr. President and Gentlemen, — A study of the causes of rainfall may have a certain interest to men engaged in water-works problems, but the study is not one which can result in modifying rainfall by anything that we can do. One of the chief results in the study of this problem is the discovery that we must take rainfall just as it comes; we cannot change it. We may utilize what comes, we may wish that more or less would come at times, but the artificial production of rainfall is believed to be practically impossible; and so also is the increase or reduction of the amount that falls. In illustration of this I will run briefly over the general physical principles involved in the occurrence of rainfall in the natural way.

In the first place, the supply of water vapor to the atmosphere comes primarily from the ocean. But it has been found by comparing the total rainfall and the total run-off of rivers that a very considerable part of our rainfall is supplied by water vapor from the lands, so that every drop falls two or three times. The vapor from the ocean falling on the land does not run directly back by streams to the ocean again, as the general statement would imply. A drop will probably fall two or three times between its departure from the ocean and its return there. The direct supply of vapor for rainfall is, therefore, not always the ocean. The vapor may come from rain that has lately fallen on the land, as a rule to windward; the rain passes off as vapor into the atmosphere and falls again, and may even fall a third time before it gets back to the ocean.

Regarding the processes of getting water out of the air, there are certain terms ordinarily used that imply a wrong physical view. For example, it is said that the air on being cooled reaches saturation. Now the word "saturation" means literally that air saturated with vapor might be compared with a saturated solution of salt in water, for example; but the analogy is a very false one, because there is no such relation between water vapor and air as there is between salt

and the water in which it is dissolved. Water will hold a certain quantity of salt at a certain temperature. It is said, when that amount is fully supplied, that the water is saturated with salt. But when the air contains as much vapor as can exist, the quantity of vapor is not determined by the mere presence of the air. The water vapor is not in any proper sense dissolved in the air; it is simply mixed with it. The air, being in much greater quantity than the water vapor which it contains, determines the temperature at which the water vapor must exist, and then the temperature given to the vapor by the presence of a much greater amount of air will determine how much vapor there may be. Indeed, water vapor can exist alone to the same quantity as in the presence of air; that is to say, water can be evaporated into a vacuum, and at a temperature of sixty degrees there might be just as much water vapor there alone, without any air to hold it, as if air were there at the same temperature. It is, therefore, the temperature of the air, and not the presence of the air, that controls the amount of vapor that may form. Again, the illustration sometimes offered of squeezing a sponge and letting the water drop from it, implying that we get rain from the air in that way, is entirely false. There is no such process at all. It is not by squeezing, or compressing the air, but, as a rule, by expanding it, that rain is caused to fall.

The vapor, being formed and mixed or diffused in the air, is carried about by the wind. Condensation will then result whenever the cooling of the air is carried to such a point that all the water vapor cannot exist as vapor; and as the cooling is continued, more and more of the vapor will be forced to condense. If the condensation is active enough, some of the condensed vapor will fall as rain or snow. So the whole process of rainfall depends on some process that will cool the air, and the vapor with it, sufficiently to provoke condensation.

The processes of cooling are various. If close to the earth's surface, the cooling of the ground by radiation at night may cause sufficient cooling of the air to condense some of the vapor from it, but the quantity thus condensed is small. Indeed, recent studies of the formation of dew have shown that a considerable part of it is not derived from the air, but is condensed from vapor rising out of the ground, or from vegetation. All sources, however, doubtless contribute to the production of dew. The amount of water thus produced is small, and not to be compared in this climate with the

abundant supply that we get from the sky, which is the result of active and abundant changes of temperature of the free air.

There are various ways in which these changes can be produced. One of them would be a poleward movement (northward in this hemisphere and southward in the other), because as a rule the temperature of the air will decrease as it moves to a higher latitude. This cooling does not, however, take place because the moving air finds colder air in its new position and is thus cooled by contact or mixture, for, as the warm air comes to its new position, the air which has been there before goes away. As the warm air goes to a higher latitude it takes a position with respect to sunshine that allows it to cool by radiation, and cooling in this way may go on sufficiently to provoke condensation, beginning, of course, by making the air cloudy, and continuing by making the clouds drip in the form of snowflakes or raindrops. But it is not ordinarily the case that cooling by poleward movement alone suffices. This process is usually supplemented by some peculiar commotion in the atmosphere. Under the general conditions of atmospheric circulation the movements of the air are not from equator towards pole, but are obliquely poleward and eastward. One might at first think that the convectional interchange between equator and pole would cause abundant movements along the meridian towards the pole, and that rainfalls thus determined would be predominant; but the rotation of the earth prevents meridional circulation and requires that the winds shall flow obliquely. On account of this motion being prevailingly oblique, the rate of cooling thus produced is very small. Theoretically this is an available process for the production of rain; practically the conditions are seldom provided to enable it to produce much rainfall.

The ascent of the air from a lower to a higher level is a most effective cause of cooling and vapor condensation wherever it can be produced. For instance, winds blowing against a mountain range must climb over the range, and in doing so they rise to a much higher level, expand and cool. This very often produces a sufficient cooling to provoke the formation of clouds and rain. It is worth noticing that the older forms of statement regarding this change are erroneous. A former way of stating it was that the air, rising to colder regions of the atmosphere, was cooled, as if by conduction to its colder surroundings, and so became cloudy. It is true that the air may rise to an altitude where the surrounding temperatures

are less than its own, but the reason that the rising air is cooled is not because it enters a region where the surrounding air is cold, but because in rising it expands, and in expanding it is mechanically cooled; it cools itself. This is a much more effective process of cooling than the mere contact of another body of cold air, for the latter process would be effective only close to the surface of contact, while expansion necessarily operates throughout the whole mass, absolutely and intimately. The ascent of air over lofty mountains is for this reason nearly always accompanied by clouds and rainfall; this must be so unless the air in beginning the ascent is extremely dry, so that in spite of an ascent of a number of thousand feet it still would not be cooled enough to become cloudy.

Cooling by ascent would be an effective process, as thus far described, only in mountain regions. For example, the westerly winds blowing from the Pacific Ocean against the coast mountains of British Columbia, or from the Atlantic against the coast mountains of Scotland and of Norway, would be provoked to cloudiness or perhaps to rainfall by this process. But rain is not limited to those regions only. Rain falls also in relatively low countries, and in such regions the rainfall is, I believe, in most cases, connected with an ascent of air not due to climbing over mountain ranges, but to climbing up in one of these great whirling bodies of air whose lower members are so well shown on the weather maps, and to whose general mass the name of "cyclonic storm" is now given. In such a commotion of the atmosphere there is oftentimes a rather active ascent of the lower air to higher levels. Not only so, but the inflowing air currents generally include an inflow which comes from the equatorial side, and this, flowing north, will cool according to the conditions which have been already stated, as well as because of the ascent. The combination of these two processes is all the more effective; it seems to be the chief cause of the rainfall that we receive. The winds, coming from southerly and moister regions towards our northern position, where they must cool, and at the same time climbing, as it were, many thousands of feet in the areas of low pressure, must become cloudy and rainy. That it is not merely the climbing around the cyclonic centers, but that the poleward movement is also a contributive cause, is shown by the general absence of rain in the northerly or northwesterly indraft of the same storm. The northwesterly winds come from a continental interior and are comparatively cold and dry; they warm as they advance,

and thus increase their capacity for vapor instead of diminishing it, while the southerly winds cool as they come towards us and hence are prevailingly cloudy and rainy.

In winter time the process thus sketched is aided still further by the contrast between the warm ocean and the cold continent. The winds that blow from the Gulf of Mexico or from the adjacent Atlantic up the Mississippi Valley or into this part of the country will, as they pass from the ocean over the land, move from warm waters to cold lands, and, so far as the temperature of the air is dependent on the interchange or radiation between the earth's surface and the air itself, this change of position tends to cause a cooling. Hence in winter the cooling caused by the poleward movement of our southerly winds around a low pressure center and the climbing of the winds around the center of low pressure is supplemented by the movement of the wind from a warm water region to a cold land region. You may notice that in the summer time an area of low pressure will generally have a less extent of cloud than in winter time, probably because at that time the winds are blowing from the water over the warm lands, and the third process of cooling just mentioned is not then operative: but also because summer storms are weaker than winter storms.

Finally, there is in the summer time an additional method of making rainfall, and that is in the sudden overturnings of the atmosphere that we see in thunder storms. In summer a very considerable share of our rainfall comes from thunder storms. This is especially true in the Mississippi Valley, where a greater rainfall occurs in the summer months, and where the summer rainfall is due in large part to thunder storms. Thunder storms seem to be due to an excessive amount of heat and moisture in the lower air, which thus becomes unstable and overturns, cooler air taking its place. The overturning is in many cases so active and the ascent so great that the ascending air becomes greatly cooled, enormous mountain-high clouds are formed, and drenching rains fall from them. The reason that the rain is as a rule of greater quantity and of greater rapidity of fall in thunder storms than in winter storms is this: In a winter storm rain or snow is condensed from the atmosphere at a relatively low temperature. In summer thunder storms the rain is condensed from the atmosphere at a decidedly high temperature, for thunder storms characterize the hottest weather we have. Now the rate of decrease of capacity for vapor in the atmosphere is not a regular

one. If saturated air is cooled from thirty degrees to twenty degrees, a certain small amount of vapor is condensed from it. If it is cooled from sixty degrees to fifty degrees a decidedly greater amount of vapor is condensed. If it is cooled from ninety degrees to eighty degrees a still greater condensation occurs than at lower temperatures. That is, the rate of decrease in capacity of the atmosphere for vapor is not constant, but is much more rapid at high temperatures than at low temperatures. It is for that reason that the same amount of disturbance in the summer gives us a heavy rain, for the cooling then will take place at high temperatures, while in winter the cooling must be at low temperatures, and the vapor then condensed will be a relatively small amount.

This explanation shows why it is that the rainfall in equatorial regions is so much greater than in high latitudes. In Greenland, for example, the total precipitation is only about ten or fifteen inches, while in many places around the equator the rainfall is eighty, ninety, or one hundred inches, and in some few places four hundred or five hundred inches. That is not so much because of the greater activity of rain-making processes in the torrid zone, but because in the equatorial regions the processes work at high temperatures, and a ten-degree cooling there will exclude a much greater amount of vapor than a ten-degree cooling in polar regions, where the process must go on at low temperatures.

A few words regarding a matter which has been much talked of in the last ten years or so, namely, the value of little solid nuclei for the beginnings of condensation. Professor Aitkin, of Edinburgh, has found reason to think that condensation of vapor into liquid is difficult, unless there are some little starting points, such as ultra-microscopic dust particles. If these particles are called "dust," the word implies something altogether too coarse for what is usually present in the atmosphere. There has been objection made to this theory, because it is found that if rainfall is carefully collected, not allowing it to wash from a roof which may be dusty, but receiving it directly in a clean tank or reservoir, it is difficult to find a significant amount of dust in it. It has been thought that inasmuch as a rain-drop may be the result of a coalescence of a vast number of smaller drops, every one of which ought to have its little dust nucleus, there ought to be in a large collection of raindrops a perceptible amount of sediment. This argument seems to be based on misapprehension; namely, the assumption that every raindrop is the result of the coa

lescence of a great number of minute drops. Consider the formation of snow. Snowdrops are of crystalline structure, and they are usually the growth from a single nucleus, not the result of the accidental coming together of various flakes. Imagine a flake begun on a single nucleus which then suffices for the rest of its growth; let it then melt, as a great deal of snow is melted, into rain; every raindrop thus formed will have but a single nucleus. Furthermore, if this be true for snowflakes, it is very likely true also for raindrops. A raindrop, then, may not be the result of the coalescence of a great many minute droplets, but of the continual condensation around a droplet which was very small at first, and which may have begun on a minute dust particle. In such case the amount of sediment to be expected from rainwater must be small, as is actually the case; and the absence of sediment cannot be used as an argument against Aitkin's theory.

Now a word with regard to the attempts to produce rain artificially. You may remember the so-called "experiment" carried on in Texas a few years ago by Dyrenforth. The peculiarity of that "experiment" was that it was no experiment at all. Dyrenforth went there with his cannon and fired away into the air, and after a time a rain came along which he claimed as his own. An experiment, as you know, involves the exclusion of all other processes than the one you are studying; Dyrenforth made no attempt whatever to exclude other processes from the origin of this rain. He did not even inquire where his rain began, although everything seems to show that it began somewhere to the west and drifted along over him after he had been firing a couple of days, and passed away east of him, with little regard to his claim of proprietorship. There does not seem to be sufficient reason to believe that rain can be produced by explosions. Curiously enough, there has just begun to be current in Europe a belief that hail can be stopped by explosions. Owners of vineyards in Switzerland say that they have found that by stationing small cannons or mortars on the hills around their vineyards, and firing away actively when a storm is seen coming towards them, the storm is dissipated, and their vines are not cut to pieces by the hailstones. This is "blowing hot and cold" with the same cannon, and it seems well to be skeptical about both of these stories.

As to other artificial methods for producing rain, there were various schemes talked of at the time when the more active settlement of the sub-arid belt in the second tier of States west of the Mississippi was

going on, some fifteen years ago. You may remember that there was then a great pressure of settlers into the region where settlement was risky because of insufficient rainfall. There was much talk then in the sub-arid belt about the rainfall; I remember when out there meeting an army officer, apparently an intelligent man, who assured me that the rainfall was actually increasing on the plains. He knew this by his experience at various stations; that it was possible to raise crops now which could not have been raised earlier, and the reason for the increased rainfall was, he said, that railroad and telegraph wires had been built across the plains, and the electric conditions of the atmosphere had thus been changed. That such a supposition is absolutely gratuitous is shown by the fact that, while there was for a few years a slightly increased rainfall, there was a very disastrous decrease afterwards, — a decrease which resulted in the abandonment of many a home and ranch because the people were simply dried out. Any attempt to increase rainfall artificially seems to me to be entirely beyond our power of accomplishment.

DISCUSSION.

The President. We have with us to-day Prof. W. H. Niles, of the Massachusetts Institute of Technology, from whom I know we should all be very glad to hear, and I will call on Professor Niles.

Professor Niles. *Mr. President and Gentlemen,* — I think I first owe you an apology, or, rather, an explanation. At the time of your last meeting, when my name was on your program, the grip had seized me for its own, and held me for twenty-five days, so I could not get to your meeting last month.

I have been interested in the remarks which have been made to you by Professor Davis on the causes of rainfall. As you have seen here, and as I have known for many years, he has a very remarkable ability for going through a very large subject, picking out the best of it, and putting things together in a very systematic manner, and then stating the results very clearly. He has so completely treated the causes of rainfall that I do not need to deal with the specific sources or how the atmosphere gets its water. But there is the other question as to how the water is taken from the atmosphere. This to me seems a very important question in its broadest relations to mankind. We think of ourselves as the inhabitants of the land,

but our earth is not land alone, — it has water and an atmosphere. The water and the atmosphere are great agents for the production of changes, and they are very beneficent in their work. It is true that there are certain agencies which are essentially atmospheric, but still we cannot dissociate the atmosphere from the water. They are so bound together that the discussion of the atmosphere at a meeting like this seems to me a very appropriate topic.

I suppose you find as you go into various places, as I have found, that there are people who have never studied into these subjects very much, and who have an idea that there may be great reservoirs of water somewhere below the surface, and that the water is not altogether derived from the atmosphere. You may have found, as I have, people who would not believe you if you were to tell them that all the water that comes to our reservoirs, our rivers, and our lakes has passed through the atmosphere, and that therefore we may call it meteoric water. The causes which combine to derive water from the atmosphere are varied, as Professor Davis has said, and some seem to act more forcibly in one section of the earth than they do in others. Some of these causes may be local and give us merely local storms, while others may be of more general efficiency. Sometimes the local causes perform the work, and at other times they do not have the opportunity because some of the more general changes in the atmosphere seem to overcome them, and then the rainfall depends upon the more widely extended influences. I believe it may be stated that the water which falls from the atmosphere comes partly in consequence of acts performed by the atmosphere itself. The atmosphere is a great working element. It derives its energy largely from differences of temperature, it is true, but it has other elements of power. In doing its work it has not only to absorb the water which has evaporated from the sea and from the land and transport it to other places, but it has its own special part to do in disposing of that moisture in the form of rain.

Professor Davis has spoken of the cyclonic storms. We often think of them as waves of the atmosphere, and we may regard them as associated with waves of high and low atmospheric pressures. It is when the atmosphere is thrown into these great waves or areas of relatively high and low pressures that it is capable of doing its largest amount of work, and it then gives us the largest supplies of rain. We have all of us experienced the fact that sometimes in the summer the clouds will gather and lower, and it looks as though it

would rain within an hour or two. The clouds sometimes continue for a long time, then gradually melt away, and no rain falls. The people in the country often say, "That was a dry storm," and that is pretty nearly true. These phenomena will sometimes be repeated a number of times, and then the people will make use of that old expression, "All signs fail in dry weather." There are whole seasons when all the conditions frequently indicate rain and yet rain does not come. How does it then happen that during some other year little clouds will come up scarcely threatening rain, when suddenly down it pours, so that people say, "It does n't take much to make it rain this year. Last year we could n't get any rain out of the atmosphere. The conditions did not seem to be right."

Now, this is explained very easily by these broad general conditions of the working power of the atmosphere. If the atmosphere has been set at work in great waves, rising in high pressures and descending in low pressures, then we may have an active atmosphere doing a large amount of work and yielding a considerable quantity of rain. Sometimes the air is calm day after day and there seems to be little change in progress; it is then that we do not get the results we want in a supply of rain. At other times there are great changes and much rain. I believe that the advantages which we receive from frequent rains and also from pure air depend very largely upon an agitated atmosphere. Professor Davis has expressed the same idea; namely, that the atmosphere must be set in motion. When we have storm following storm, and when we have clear weather following each, we then have the atmosphere at work. It not only transports the aqueous vapor from the sea, but it also promotes those upward currents, which are the efficient causes of precipitation. We sometimes hear people talk about leveling the areas of human action so that each man shall have the same wages that every other man has. They seem to think that is the great panacea for all the evils in society, to have all distinctions removed. But nature does not work in that way; she raises the pressure of the atmosphere in one place and reduces it in another, and it is these differentiations which give us some of the best results which come from an atmosphere yielding copious and frequent supplies of rain.

We are then living under an atmosphere which has movements that are too extended, too energetic, and too capricious for us to control. The floods threaten us with dangers, and if the rain is withheld we suffer. How may the evil be averted and the good be

retained? Only by the storage of the water the atmosphere gives us. For this we must utilize our lakes and our forests, and we must have the best means for holding and supplying us with water that engineers can construct.

This is the great work, gentlemen, to which you have the honor of applying your skill and of directing your best efforts.

Mr. George F. Chace.* I should like to ask Professor Davis one question. He may have answered it already, but if he did I overlooked it. Since 1876, when our water works were built in Taunton, we have kept a record of the rainfall at the pumping station in Taunton. Ten miles and a half from Taunton, on the shores of Assowompsett Pond, we have another pumping station, at which a record of the rainfall has been kept since 1894; and the methods of collecting the rain and keeping the record are precisely the same at both places, being the methods prescribed by the United States Weather Bureau. Now, every single year the annual rainfall at Lakeville, at the pumping station, has been less than at the pumping station at Taunton. There is a water area in that vicinity, so far as I can remember roughly, of between five thousand and six thousand acres. I should like to ask the professor what relation that water area in the vicinity of the collection of the rainfall has to the amount of rainfall.

Professor Davis. Mr. President, the best way to answer this question is not in my power. The best way is to go down to Taunton and study the matter out, perhaps spend ten years on it, and get at the facts by direct observation. If observations were made not merely on the rainfall in two places, but in twenty or in two hundred, all around the pond, on it, near it, and away from it, you would find out something which would certainly be very interesting, but even then it may be that the answer to the question would not be found. Nevertheless, this would be the best way to try to find the answer. On the other hand, one can always hazard an opinion on matters of this sort, in view of general principles; but general principles, so far as I can apply them, do not at present enable us to explain any local variation of rainfall in distances of three or four, or of five or ten miles, in a country so generally even and low as southeastern Massachusetts. What we should expect to cause rainfall there is not this hill or that valley, or this plain, field, or lake. None of those small local features can be shown to have power to effect those large movements

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* Superintendent, Taunton Water Works.

of the atmosphere on which rainfall seems to depend. In order to get some understanding of the causes of rainfall, we are driven to the large movements of the atmosphere, and such movements do not seem to be produced by small local causes.

The rain clouds that pass from west to east or from southwest to northeast across our State pay very little attention indeed to small matters of topography. The records taken some years ago show that the clouds take no account at all of small matters in the way of giving more or less rainfall. Some fifteen years ago a small organization, known as the New England Meteorological Society, which some of the members present may recall, undertook the special study of thunder storms; we had something over two hundred volunteer observers, scattered all over southern New England. They reported on a systematic plan the time of beginning of the rainfall, the time it ended, the first thunder, loudest thunder, last thunder, the direction of the wind, changes of temperature, and so on. Now, one of the results of that study was the discovery that our thunder storms, as they swept across the country, did not, as far as we could tell with records of a considerable degree of detail, pay any attention to hill or valley, river, pond, or anything of the sort. We very frequently hear it said, "Thunder storms don't often come here; they go south along that valley, or north along that valley," but we found no proof of such behavior from our records. In one particular case, the storm was found entering New England from New York at about eight o'clock in the morning. It came directly across the Hudson River valley, eastward right upon the Berkshire Hills, about where Connecticut and Massachusetts join, across those hills, straight across the depression of the Connecticut valley, over the central highlands, right on across the southeastern part of the State, across Cape Cod Bay and over Cape Cod. It did not turn to the right nor to the left, it did not hurry, it did not slacken, but went on increasing in strength as the day advanced, and giving a brief but abundant rainfall as it passed. It did not seem to care in the least for any local conditions.

Therefore, with regard to this question of the difference in rainfall between Taunton and the lake, general principles do not offer any answer whatever, because all the general principles seem to refer to the large processes that are at work aloft in the air, and not to the small processes down close to the ground. But I wish very much that local studies might be taken up, and it does not seem to

me there can be any better place for them to be studied than by such au association as this, which of course must keep a number of records at stations all about, and might add to those records by multiplying them by ten or twenty. I should like very much indeed to see the results that might then be reached.

THE EFFECT OF WATER METERS ON WATER CONSUMPTION IN THE LARGER CITIES OF THE UNITED STATES.

BY GEORGE I. BAILEY, SUPERINTENDENT BUREAU OF WATER, ALBANY, N. Y.

[*Reprinted from Engineering News of April 18, 1901.*]*

Conditions arising in the operation of the water works of the city of Albany made it desirable for its officers to have information concerning the water supply of other cities.

The conditions were, an enormously increased consumption of water during the winter, almost an even rate of consumption for each hour of the twenty-four, and an insufficient pressure in high portions of the city, all of which created an urgent demand for furnishing greater quantities of water, which meant a general addition to our plant, or else methods for restricting waste.

The general conditions are not new, and as they either have occurred or will occur in almost every city, they are assumed to be of interest to water-works officials. All of these conditions sum up in the question, whether it is cheaper and better for water takers to waste water or not to waste it. It is an easy matter to give reliable estimates of cost for increasing the plant, and for furnishing and placing water meters. There is a lack of information as to how well water meters will control the supply, their life, their operating cost, and their effect upon the water taker's pocketbook. Although there is an abundance of evidence as to what has occurred in special cases and locations, we know of no general summary.

For our information we wrote to every city in the United States having a population of 25 000 people or over by the census of 1900. We received replies from 136 of the 159 cities. Available information on quantity of water furnished daily was given by 134 cities, having an aggregate population of 17 650 000. Available information on receipts from water was given by 102 cities, having a total

* This paper deals with a subject of so great importance to all water-works managers and contains so much valuable information that the editor has no apology to offer for reprinting it, although it was not presented to this Association.

population of 15 814 000. In each case the population represents more than twenty per cent. of the total population of the United States. The locations of the cities are widespread, and therefore the averages are representative. The cities which refused information were generally those whose water supply was controlled by private companies.

We find the average per capita consumption in these American cities to be 137 gallons. The effect of placing water meters is as follows: —

Taps Metered.	Consumption. Daily, per Capita, Gallons.	Consumption. Per Cent. of Average.
Less than 10 per cent	153	112
10 to 25 per cent	110	80
25 to 50 per cent	104	76
More than 50 per cent	62	45

In cities where the number of consumers was not given, we assumed that the total population was supplied. We understand that it is rare for a city to supply all its people with water, and to offset this overestimate we have taken into account that most cities have at least a partial supply received from pumps, and that the universal rule is to credit the full quantity of water calculated on plunger displacement without making any allowance for slip or leakage of pumps. The gaging of the Croton Aqueduct made by Mr. John R. Freeman, for the comptroller of the city of New York, shows an overstatement of quantity delivered by gravity through that aqueduct, and this overstatement we believe applies approximately to all such supplies. We believe, therefore, the overestimate of population is equalized by the overstatement of quantity supplied.

Where the total number of taps was not given we assumed one tap to six persons. These assumptions and some misunderstanding of questions by different officials may make slight differences, but the numbers used are so large that they would not materially affect the results.

In all cases cities were asked to state the number of consumers. There is a decided difference of opinion among water-works officials as to what constitutes a consumer. In the Northeastern and Middle States a consumer is understood to be an individual. In most of the other cities a consumer is considered a collective number of individuals, either a family or colony, supplied from a single tap. As

TABLE I.—WATER CONSUMPTION, USE OF METERS, AND RECEIPTS FOR WATER IN OVER ONE HUNDRED OF THE LARGEST CITIES OF THE UNITED STATES.*

(Compiled from Special Official Reports by George I. Bailey, Superintendent of the Bureau of Water, Albany, N. Y.

Rank in Population.	CITIES.	Population. By Census of 1900.	Population. Supplied.	Consumption (Gallons per Day). Total.	Consumption (Gallons per Day). Per Consumer.	Average Annual Receipts. Total.	Average Annual Receipts. Per Consumer.	Number of Taps.	Meters in Use.	Percentage of Taps Metered.	Meters Furnished by †	Meters Set by †
87.	Akron, Ohio	42 728	20 000	....	200	Private.	....	4 276	400	9.35	D	D
40.	Albany, N. Y.	94 151	95 000	18 100 000	191	$292 000	$3.07	16 500	2 030	12.30	D	B
113.	Allentown, Pa.	35 416	37 000	4 357 000	118	61 800	1.70	......	17	....	C	C
96.	Altoona, Pa.	38 975	37 900	....	95	68 000	1.79	8 496	225	2.64	D	D
43.	Atlanta, Ga.	89 872	65 000	5 444 000	84	133 800	2.06	9 275	8 500	91.64	C	C
148.	Atlantic City, N. J.	27 838	28 500	....	80	110 000	3.86	4 249	3 298	77.62	D	D
135.	Auburn, N. Y.	30 345	....	4 500 000	148	75 000	2.47	5 000	400	8.00	D	D
6.	Baltimore, Md.	509 000	576 000	56 000 000	97	950 000	1.65	110 000	1 607	1.46	C	C
150.	Bay City, Mich.	27 628	17 000	3 000 000	177	45 000	2.65	2 200	826	37.54	D	C
124.	Bayonne, N. J.	32 722	....	3 071 000	94	139 000	4.25	3 000	3 000	100	C	C
93.	Binghamton, N. Y.	39 647	....	5 936 000	156	95 000	2.47	7 000	523	7.47	B	D
5.	Boston, Mass.	560 900	....	80 000 000	143	2 233 000	3.98	81 000	4 455	5.50	D	D
54.	Bridgeport, Conn.	70 996	70 000	16 500 000	236	Private.	....	8 000	171	2.14	D	D
92.	Brockton, Mass.	40 063	35 000	1 165 000	32	77 000	2.20	5 275	4 300	81.51	C	C
8.	Buffalo, N. Y.	352 400	400 000	92 365 000	233	650 000	1.62	64 638	1 049	1.62	..	..
133.	Butte, Mont.	30 470	45 000	....	100	Private.	....	5 531	341	6.17	D	D
41.	Cambridge, Mass.	91 886	....	....	79	324 000	3.53	14 207	860	6.05	D	D
62.	Camden, N. J.	75 935	50 000	14 000 000	280	161 000	3.22	14 000	197	1.41	D	D
132.	Canton, Ohio	30 667	....	3 750 000	122	36 000	1.17	4 300	45	1.05	B	C
157.	Cedar Rapids, Ia.	25 656	....	3 000 000	117	Private.	....	2 800	60	2.14	D	C
68.	Charleston, S. C.	55 807	....	1 800 000	32	Private.	....	1 750	20	1.14	C	C
117.	Chelsea, Mass.	34 072	....	3 000 000	88	88 000	2.58	6 146	118	1.92	D	D
2.	Chicago, Ill.	1 698 600	....	323 000 000	190	3 250 000	1.91	200 000	6 500	3.25	C	C
10.	Cincinnati, Ohio	325 900	....	39 600 000	121	764 000	2.34	36 000	2 745	7.63	C	C
7.	Cleveland, Ohio	381 800	420 000	66 900 000	159	766 000	1.82	63 632	3 143	4.94	B	B
28.	Columbus, Ohio	125 560	100 000	23 000 000	230	165 000	1.65	14 608	4 960	33.95	C	C
156.	Council Bluffs, Ia.	25 802	....	2 000 000	78	Private.	....	2 761	557	20.17	B	B
86.	Covington, Ky.	42 938	....	2 500 000	58	75 000	1.75	5 300	4 150	78.30	D	D
114.	Davenport, Ia.	35 254	20 000	3 000 000	150	Private.	...	4 000	1 500	37.50	D	D
45.	Dayton, Ohio	85 333	....	5 300 000	62	133 000	1.56	12 000	5 600	46.67	D	B
25.	Denver, Col.	133 859	100 000	....	300	Private.	....	23 549	282	1.19	C	C
69.	Des Moines, Ia.	62 139	....	3 000 000	48	Private.	....	7 499	4 289	57.19	D	C
14.	Detroit, Mich.	285 700	306 055	44 800 000	146	465 000	1.52	55 340	5 555	10.04	D	D
107.	Dubuque, Ia.	36 297	....	2 500 000	69	74 000	2.04	1 980	125	6.31	C	C
72.	Duluth, Minn.	52 969	15 000	4 100 000	273	133 000	8.87	2 795	1 261	45.11	C	C
158.	Easton, Pa.	25 238	25 000	2 000 000	80	....	....	2 200	100	4.55	D	D
112.	Elmira, N. Y.	35 672	20 000	4 500 000	225	Private.	....	4 000	612	15.30	D	D
73.	Erie, Pa.	52 733	....	7 458 000	142	139 000	2.64	11 163	266	2.38	D	D
64.	Evansville, Ind.	59 007	....	8 000 000	136	76 500	1.30	5 367	12	0.21	D	D
33.	Fall River, Mass.	104 863	104 500	3 805 000	36	168 600	1.61	6 943	6 544	94.25	C	C
128.	Fitchburg, Mass.	31 531	25 000	3 000 000	120	68 500	2.74	4 437	2 427	54.70	B	B
83.	Fort Wayne, Ind.	45 115	....	3 500 000	78	55 000	1.22	7 804	1 400	17.94	C	C
151.	Fort Worth, Tex.	26 688	30 000	3 000 000	100	84 266	2.81	3 209	247	7.75	D	B
153.	Gloucester, Mass.	26 121	....	950 000	36	76 000	2.91	2 817	56	1.99	D	C
44.	Grand Rapids, Mich	87 565	....	13 693 000	156	125 946	1.44	8 901	1 193	13.40	?	B
77.	Harrisburg, Pa.	50 167	57 000	8 202 500	144	115 800	2.03	12 000	4 278	35.65	B	C
49.	Hartford, Conn.	79 850	80 000	8 500 000	106	250 000	3.12	9 351	2 550	27.27	D	D
104.	Haverhill, Mass.	37 175	38 000	....	95	96 400	3.01	5 300	550	10.38	D	C
82.	Holyoke, Mass.	45 712	45 700	....	..	90 042	1.97	3 610	210	5.82	C	D
21.	Indianapolis, Ind.	169 164	....	13 400 000	79	325 000	1.92	10 046	600	5.97	D	C
159.	Jackson, Mich.	25 180	....	....	100	30 000	1.19	3 300	400	12.12	D	D
142.	Jacksonville, Fla.	28 429	20 000	2 136 000	107	53 649	2.68	2 335	1 154	49.42	D	D
17.	Jersey City, N. J.	206 433	200 000	32 020 000	160	838 000	4.19	25 000	500	2.00	D	D
111.	Johnstown, Pa.	35 936	33 000	4 750 000	144	Private.	....	4 100	40	0.98	D	D
137.	Joliet, Ill.	29 353	....	3 000 000	102	....	....	2 500	300	1.20	C	C
22.	Kansas City, Mo.	163 752	....	....	62	420 000	2.56	13 000	5 200	40.00	C	C
76.	Kansas City, Kan.	51 418	....	4 301 000	84	Private.	....	2 370	750	31.65	C	C
125.	Knoxville, Tenn.	32 637	23 400	2 800 000	120	Private.	....	4 250	380	8.94	B	B
140.	La Crosse, Wis.	28 895	29 000	5 585 000	193	33 150	1.14	3 300	40	1.21	C	C
90.	Lancaster, Pa.	41 459	....	6 000 000	145	103 000	2.48	6 000	500	8.33	B	B
57.	Lawrence, Mass.	62 569	57 200	3 204 000	56	103 600	1.81	5 926	4 386	74.01	C	C
152.	Lexington, Ky.	26 369	....	1 250 000	47	Private.	....	1 500	1 482	99.47	D	C
91.	Lincoln, Neb.	40 169	25 000	2 000 000	80	40 000	1.60	3 550	2 000	56.34	C	C
36.	Los Angeles, Cal.	102 479	90 000	17 000 000	189	Private.	....	22 000	600	2.72	B	B
18.	Louisville, Ky.	204 731	160 000	....	100	557 000	3.48	20 755	1 560	7.52	D	D
39.	Lowell, Mass.	94 969	94 000	8 000 000	85	202 000	2.15	10 634	5 586	52.53	C	C
55.	Lynn, Mass.	68 513	73 000	4 660 000	64	210 000	2.88	12 577	2 500	19.88	B	B
120.	Malden, Mass.	33 664	....	1 700 000	50	112 000	3.33	6 426	2 935	45.67	D	D
65.	Manchester, N. H.	56 987	....	3 500 000	61	138 000	2.42	5 500	3 700	67.27	D	D
115.	McKeesport, Pa.	34 227	....	2 500 000	73	50 000	1.46	3 833	754	19.67	B	C
37.	Memphis, Tenn.	102 320	80 000	10 000 000	125	Private.	....	9 666	800	8.28	D	D
15.	Milwaukee, Wis.	285 300	300 000	24 000 000	80	430 000	1.43	41 485	28 039	67.59	C	C
19.	Minneapolis, Minn.	202 718	....	18 813 000	93	225 000	1.11	18 800	5 176	27.53	B	C
98.	Mobile, Ala.	38 469	19 500	2 800 000	144	36 300	1.86	3 890	31	0.80	D	D
47.	Nashville, Tenn.	80 865	....	11 300 000	140	140 000	1.73	7 720	3 200	41.45	B	B
16.	Newark, N. J.	246 070	255 000	24 000 000	94	690 300	2.71	33 500	7 342	21.92	B	B
58.	New Bedford, Mass.	62 442	55 000	6 320 000	115	181 600	3.30	9 280	1 429	15.40	B	B
155.	New Britain, Conn.	25 998	25 000	....	160	56 400	2.26	3 259	180	5.52	C	C
31.	New Haven, Conn.	108 027	....	....	150	Private.	....	14 500	375	2.58	D	D
13.	New Orleans, La.	287 100	....	13 820 000	48	Private.	....	......	....	....	C	C
144.	Newport, Ky.	28 301	....	2 000 000	71	55 000	1.94	5 000	470	9.40	C	C
122.	Newton, Mass.	33 587	32 800	2 086 000	64	131 000	3.99	7 087	6 001	84.68	C	D
1.	New York, N. Y.	3 437 200	....	400 000 000	116	6 200 000	1.80	......	44 000	....	C	C
80.	Norfolk, Va.	46 624	40 000	5 250 000	131	115 000	2.88	8 500	178	2.09	C	C
56.	Oakland, Cal.	66 960	80 000	12 500 000	156	367 000	4.46	16 900	1 130	6.69	D	D
35.	Omaha, Neb.	102 555	....	18 000 000	176	Private.	....	11 000	3 800	34.55	C	C
145.	Oshkosh, Wis.	28 284	....	2 500 000	88	Private.	....	1 773	51	2.88	C	C
149.	Passaic, N. J.	27 777	....	2 500 000	90	Private.	....	2 900	929	32.03	D	D
32.	Paterson, N. J.	105 171	98 000	12 600 000	129	Private.	....	11 108	2 299	20.71	D	D
95.	Pawtucket, R. I.	39 231	80 000	6 524 000	82	193 000	2.41	8 293	6 369	76.80	B	B
67.	Peoria, Ill.	56 100	....	3 500 000	62	Private.	....	6 058	418	6.90	D	D
3.	Philadelphia, Pa.	1 293 700	1 254 000	287 188 000	229	3 047 900	2.43	250 000	1 275	0.51	D	D
11.	Pittsburg, Pa.	321 600	234 000	64 000 000	231	806 000	3.44	33 084	200	0.60	C	C
42.	Portland, Ore.	90 426	90 000	18 000 000	200	286 000	3.18	12 447	509	4.09	D	D
20.	Providence, R. I.	175 597	187 300	10 130 000	54	577 587	3.08	21 566	17 813	82.60	C	C
147.	Pueblo, Col.	28 157	15 000	4 000 000	267	62 500	4.17	3 400	30	0.88	D	D
108.	Quincy, Ill.	36 252	....	1 650 000	46	Private.	....	2 700	1 300	48.15	D	C
139.	Racine, Wis.	29 102	....	1 360 000	47	Private.	....	4 916	1 200	24.41	B	C
50.	Reading, Pa.	78 961	77 900	7 180 000	92	161 100	2.07	15 885	636	4.00	B	C
46.	Richmond, Va.	85 050	....	10 048 000	100	140 000	1.65	14 781	4 500	30.44	B	D
24.	Rochester, N. Y.	162 608	....	13 500 000	83	400 000	....	34 549	8 752	25.33	C	C
130.	Rockford, Ill.	31 051	22 000	2 600 000	118	38 900	1.77	3 373	270	8.00	D	D
89.	Saginaw, Mich.	42 345	28 000	7 500 000	268	45 000	1.61	3 500	300	8.57	D	D
4.	St. Louis, Mo.	576 200	400 000	63 530 000	159	1 483 000	3.71	65 688	4 133	6.29	B	B
23.	St. Paul, Minn.	163 065	125 000	8 337 000	67	346 000	2.77	17 093	4 812	28.15	B	C
110.	Salem, Mass.	35 956	35 700	....	70	80 000	2.24	6 400	180	2.81	D	D
70.	Salt Lake City, Utah	53 531	55 000	12 000 000	218	100 000	1.82	12 000	145	1.21	D	D
71.	San Antonio, Tex.	53 321	....	8 500 000	159	Private.	....	9 100	100	1.10	B	B
9.	San Francisco, Cal.	342 800	....	25 000 000	73	Private.	....	43 000	9 900	23.02	D	D
69.	Savannah, Ga.	54 244	55 000	6 000 000	109	80 000	1.45	8 000	45	0.56	C	C
127.	Schenectady, N. Y.	31 682	27 000	6 000 000	222	75 000	2.78	7 000	20	0.29	D	D
123.	Sioux City, Ia.	33 111	....	1 427 000	43	43 600	1.32	3 000	1 525	50.83	B	C
48.	Seattle, Wash.	80 671	60 000	8 500 000	142	200 473	3.34	6 181	800	12.94	D	D
105.	Spokane, Wash.	36 848	32 000	7 925 000	248	157 500	4.92	5 000	165	3.30	D	C
61.	Somerville, Mass.	61 643	62 000	....	88	210 000	3.39	10 000	200	2.00	D	D
60.	Springfield, Mass.	62 059	48 200	5 471 500	113	243 700	5.06	9 764	3 122	31.97	C	C
101.	Springfield, Ohio	38 253	33 000	3 000 000	91	43 000	1.30	4 200	200	4.76	B	D
116.	Springfield, Ill.	34 159	18 000	4 000 000	222	67 000	3.72	3 000	230	7.67	C	C
129.	Superior, Wis.	31 091	....	2 000 000	64	Private.	....	1 800	140	7.77	C	C
30.	Syracuse, N. Y.	108 374	....	11 000 000	102	273 000	2.52	17 000	8 037	47.28	C	C
103.	Tacoma, Wash.	37 714	40 000	4 000 000	100	95 000	2.37	4 500	500	11.11	D	D
131.	Taunton, Mass.	31 036	26 100	1 620 000	62	60 600	2.32	4 502	1 832	40.69	C	D
106.	Terre Haute, Ind.	36 673	....	3 500 000	95	Private.	....	4 265	285	6.68	D	D
26.	Toledo, Ohio	131 822	65 384	7 750 000	119	140 000	2.14	11 888	5 975	50.26	C	C
121.	Topeka, Kan.	33 608	....	1 900 000	56	Private.	....	2 900	550	18.97	B	B
53.	Trenton, N. J.	73 305	71 610	7 090 000	99	116 700	1.63	......	190	....	D	D
62.	Troy, N. Y.	60 651	58 000	10 600 000	183	104 500	1.80	7 500	314	4.19	D	C
66.	Utica, N. Y.	56 383	....	3 000 000	53	Private.	....	7 064	6 838	96.80	C	C
81.	Waterbury, Conn.	45 859	....	6 000 000	131	115 500	2.51	4 899	486	9.92	D	D
12.	Washington, D. C.	287 700	270 000	50 000 000	185	350 000	1.30	45 000	1 200	2.67	C	C
97.	Wheeling, W. Va.	38 878	....	9 500 000	244	100 000	2.52	......	6	....	D	D
61.	Wilmington, Del.	76 508	76 500	6 930 000	90	162 300	2.12	15 000	640	4.27	D	D
141.	Williamsport, Pa.	28 757	26 000	4 500 000	173	Private.	....	4 371	85	1.94	D	D
146.	Woonsocket, R. I.	28 204	32 000	933 000	29	72 800	2.28	2 347	2 136	91.01	D	D
29.	Worcester, Mass.	118 421	113 000	7 920 000	70	262 175	2.32	13 292	12 536	94.31	C	C
79.	Yonkers, N. Y.	47 931	45 000	3 627 000	81	147 944	3.29	4 968	4 852	97.67	C	C
119.	York, Pa.	33 708	36 000	2 850 000	79	93 000	2.58	8 300	275	3.31	D	D

* The average per capita consumption and receipts are based on the population supplied, where reported; otherwise, on the population by census of 1900.

† D = Department; C = Consumer; B = Both.

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we did not understand exactly what was meant in the several cases, we adopted the method stated above.

In regard to cost, we find $2.25 to be the annual per capita cost for water in all cities, indicating no difference in dollars alone to the water consumer for whatever method of charge is adopted. This is surprising, especially as it follows out in each of the metered percentage groups, and it would almost appear to be simply a coincidence. It may be explained that as the general use of water meters is comparatively recent in American cities, and as the works were installed and the water debt incurred before the use of meters, a sufficient time has not elapsed for them to have had their full effect on the water rates. If it is a coincidence, it shows conclusively that meter charges do not, as claimed, increase the cost to consumers.

A summary and averages of the detailed figures given in Table I are presented in Table II, classified in accordance with the percentage of taps metered.

TABLE II. — Population, Water Consumption, and Receipts for Water, Summarized and Averaged in Accordance with Percentage of Taps Metered.*

Percentage of Taps Metered.	Number of Cities.	Population.*	Consumption (Gallons per Day). Total.	Average per Consumer.	Number of Cities.	Population.*	Receipts. Total.	Average per Consumer.
0 to 10	71	12 713 866	1 947 378 000	153	53	11 802 154	$26 432 316	$2.24
10 to 25	18	1 657 454	182 991 000	110	12	1 108 142	2 491 719	2.25
25 to 50	22	1 686 635	175 632 000	104	17	1 448 633	3 255 149	2.25
50 to 100	23	1 600 333	109 616 000	62	20	1 455 442	3 253 606	2.24
Totals and Averages	134	17 658 288	2 415 617 000	137	102	15 814 371	$35 432 790	$2.24

The results obtained are general, apply to no especial city or location, and their only purpose is to afford figures for ready comparison, and to identify the thing we have all heard of and never have seen, namely, the per capita consumption of water in American cities.

There is one result that stands forth preëminently, namely, that

* The table is based on the population supplied, where separately reported; otherwise on the total population by the census of 1900.

the average per capita consumption is twice as great as it should reasonably be, and that cities which are now in distress from danger of a water famine, and are consequently in search of additional supplies, can, by applying proper methods of conservation to their present supplies, more quickly and cheaply relieve themselves from their distresses, and by so doing have an abundant and adequate supply of water for twice as many inhabitants as they now have.

EDITORIAL DISCUSSION IN "ENGINEERING NEWS."

Selling water by guess has now few advocates among water-works engineers and superintendents. In fact, nearly all men held directly responsible for ample and pure municipal water supplies have had the necessity of using meters forced home in such a variety of ways that they now believe in as rapid an extension of the meter system as popular feeling, or prejudice, will permit. The extent to which these convictions, on the one hand, and prejudices on the other, prevail in the larger cities of the United States is indicated by the foregoing figures on water consumption and the use of meters during the year 1900. The responses made to Mr. Bailey's inquiries, both in numbers and completeness, reflect in no small degree the interest which the subject now excites in the minds of water-works officials. The replies are also a gratifying example of the spirit of coöperation which exists among the more intelligent and specially trained class of municipal officials.

The important results of Mr. Bailey's work are condensed in a half-dozen lines, showing that the average daily per capita water consumption of 134 cities was 137 gallons; that those having less than 10 per cent. of their taps metered consumed 153 gallons; while the average per capita consumption where over 50 per cent. of the taps were metered was only 62 gallons, or 45 per cent. of the average for the whole 134 cities.

Some comparison between conditions existing in 1900 and in 1890 may be interesting and profitable. *Engineering News* of January 16, 1892, contained statistics showing the consumption of water and use of meters in the fifty largest cities of the United States, and in all other communities having 50 per cent. or more of their taps metered.* In Table III, herewith, we have compared these earlier figures with

* Based on figures given in "The Manual of American Water Works for 1891." The article in question will be found also in the introduction to the "Manual" for the year named.

TABLE III. — PERCENTAGE OF TAPS METERED AND PER CAPITA WATER CONSUMPTION IN THE FIFTY LARGEST CITIES OF THE UNITED STATES IN 1890 AND IN 1900, ARRANGED IN ORDER OF POPULATION.*

	Cities.	Percentage of Taps Metered.		Per Capita Consumption (Gallons).		Increase or Decrease of Consumption in 10 Years (Gallons).
		1890	1900	1890	1900	
1.	New York †	20.2	..	79	116	+ 37
2.	Chicago	..	3.3	140	190	+ 50
3.	Philadelphia	0.3	0.5	132	229	+ 97
4.	Brooklyn †	2.5	..	72	...	..
5.	St. Louis	8.2	6.3	72	159	+ 87
6.	Boston	5.0	5.5	80	143	+ 63
7.	Baltimore	0.1	1.5	94	97	+ 3
8.	San Francisco	41.4	23.0	61	73	+ 12
9.	Cincinnati	4.1	7.6	112	121	+ 7
10.	Cleveland	5.8	4.9	103	159	+ 56
11.	Buffalo	0.2	1.6	186	233	+ 47
12.	New Orleans	0.4	..	37‡	48‡	+ 11
13.	Pittsburg	0.2	0.6	144	231	+ 87
14.	Washington	0.3	2.7	158	185	+ 27
15.	Detroit	2.1	10.0	161	146	— 15
16.	Milwaukee	31.9	67.6	110	80	— 30
17.	Newark	2.4	21.9	76	94	+ 18
18.	Minneapolis	6.3	27.5	75	93	+ 18
19.	Jersey City	1.2	2.0	97	160	+ 63
20.	Louisville	5.9	7.5	74	100	+ 26
21.	Omaha	19.4	34.6	94	176	+ 82
22.	Rochester	11.4	25.3	66	83	+ 17
23.	St. Paul	4.2	28.2	60	67	+ 7
24.	Kansas City	17.6	40.0	71	62	— 9
25.	Providence	62.4	82.6	48	54	+ 6
26.	Denver	0.8	1.2	..	300	..
27.	Indianapolis	7.6	6.0	71	79	+ 8
28.	Allegheny	0.0	..	238	..	..
29.	Albany	0.4	12.3	..	191	..
30.	Columbus	6.4	34.0	78	230	+152
31.	Syracuse	14.6	47.3	68	102	+ 34
32.	Worcester	89.4	94.3	59	70	+ 11
33.	Toledo	9.4	50.3	72	119	+ 37
34.	Richmond	1.4	30.4	167	100	— 67
35.	New Haven	..	2.6	135	150	+ 15
36.	Paterson	..	20.7	128	129	+ 1
37.	Lowell	22.9	52.5	66	85	+ 19
38.	Nashville	0.8	41.5	146	140	— 6
39.	Scranton	..	...	..	..	..
40.	Fall River	74.6	94.3	29	36	+ 7
41.	Cambridge	2.4	6.1	64	79	+ 15
42.	Atlanta	89.6	91.6	36	84	+ 48
43.	Memphis	3.7	8.3	124	125	+ 1
44.	Wilmington	0.2	4.3	113	90	— 23
45.	Dayton	3.8	46.7	47	62	+ 15
46.	Troy	3.9	4.2	125	183	+ 58
47.	Grand Rapids	..	13.4	..	156	..
48.	Reading	0.1	4.0	75	92	+ 17
49.	Camden	..	1.4	131	280	+149
50.	Trenton	..	..	62	99	+ 37

* The classification is by the census of 1890, so as to include all the cities in the earlier grouping.
† New York and Brooklyn consolidated since 1890.
‡ Only a small part of the population supplied.

those given in Mr. Bailey's article, stopping, however, with the fifty largest cities in the 1890 list. The final column of the table gives the increase or decrease in per capita consumption during the ten years from 1890 to 1900.

Perhaps it should be pointed out that the figures for consumption ought not to be compared in too great detail, since all the 1890 averages of consumption were based on the total populations of the respective cities, while Mr. Bailey used, for his computations, the actual populations supplied, when reported; otherwise, the 1900 census figures. Mr. Bailey was justified in this, since he contents himself with giving the actual figures reported and a few broad generalizations, based on averages. Notwithstanding the possible discrepancies named, it seemed desirable to place the two sets of figures side by side, for comparison, with the suggestion that the warning here given be kept in mind. A reference to Mr. Bailey's Table I will show whether his per capita consumption is based on the 1900 census or the estimated population supplied. Perhaps the most notable instance of the difference in results obtained by the two methods is shown by St. Louis. According to Table III, its per capita consumption increased from 72 to 159 gallons, in the ten years, from 1890 to 1900. But Mr. Bailey's report from St. Louis placed the population supplied at 400 000, while the 1900 census showed a total population of 575 200. Using the latter figure as a divisor, the per capita consumption in St. Louis for 1900 was 110 gallons, or an increase of 53 per cent. over 1890, instead of 120 per cent. Even the 53 per cent. is bad enough. It is to be accounted for, at least in part, by a diminution of the percentage of taps metered, which was 8.2 in 1890, and 6.3 in 1900. The same sort of calculation helps to explain why a marked increase in the use of meters at Columbus, Ohio, from 6.4 to 34.0 per cent., should be accompanied with an increase in consumption from 78 to 230 gallons, or nearly 200 per cent. The report sent to Mr. Bailey from Columbus gave the population supplied as 100 000; the total population in 1900 was 125 560. On the latter basis, the per capita consumption becomes 183 gallons. In addition to this, the 1900 returns show that there was one tap in use for every 8.6 consumers, whereas the consumers per tap in 1890 averaged 11.5. In other words, using the total population in 1890 to find the per capita consumption was more misleading than in 1900, since relatively fewer people were supplied with water then. Thus the wisdom of using the actual population supplied, when you can

get it, is emphasized. On the other hand, it is evident that the round 100 000 population in Mr. Bailey's table is merely a local guess, and by adopting such guesses for some cities and using total populations for others, where guesses are perhaps more needed, it is questionable whether the comparative value of the figures is made greater than when total population is used. This is particularly true in a census year. At other times, all the populations are guesses. If an estimate of the population actually supplied is needed anywhere it is in the case of New Orleans. No such estimate was reported, so Mr. Bailey used the total population, thus showing an apparent consumption of 48 gallons per capita in a city having but 0.4 per cent. of its taps metered. In justice to Mr. Bailey, we again call attention to the fact that his main idea was to secure broad general averages, which may be but little affected by the above considerations. Probably there is not another large city in the United States where so small a proportion of the population uses the public water supply. When the city regains control of the works, and installs a purification plant in accordance with the teachings of the investigations it now has under way, probably the people will go back from their cisterns to the public water supply which so many of them abandoned years ago on account of its muddiness.

Leaving these details and possible discrepancies, one may find plenty of instruction from the broad general teachings of the comparative figures. As a rule, the cities that show the greatest increase in consumption also show but little increase in relative number of meters used, while many of the notable and some of the small increases in meter percentages are accompanied by notable decreases in consumption. The five cities with decreased consumptions have each made decided gains in the percentages of taps metered.

To make it still more evident that, as a rule, cities with high consumption employ but few meters, the figures for both 1890 and 1900, given in Table III, have been rearranged in Table IV, in order of consumption per capita, greatest to least. It will be noticed that in 1890 all the cities, with one exception, using over 100 gallons a day, had less than six per cent. of their taps metered. This exception was Milwaukee, which had 31.9 per cent. of its taps metered in 1890 and stood No. 17 in the list. In 1900 Milwaukee had 67.6 per cent. of its taps metered; its consumption had fallen to 80 gallons, and its rank to No. 37. It is very significant that the list for 1900 shows 28 cities with a consumption of 100 gallons and more per capita,

TABLE IV.—WATER CONSUMPTION AND PERCENTAGE OF TAPS METERED IN THE LARGEST CITIES OF THE UNITED STATES, ARRANGED IN ORDER OF CONSUMPTION.*

In 1890.				In 1900.			
Rank.	City.	Consumption (Gallons).	Percentage of Taps Metered.	Rank.	City.	Consumption (Gallons).	Percentage of Taps Metered.
1.	Allegheny	238	0.0	1.	Denver †	300	1.2
2.	Buffalo	186	0.2	2.	Allegheny	?	?
3.	Richmond	167	1.4	3.	Camden	280	1.4
4.	Detroit	161	2.1	4.	Buffalo	233	1.6
5.	Washington	158	0.3	5.	Pittsburg	231	0.6
6.	Nashville	146	0.8	6.	Columbus	230	34.0
7.	Pittsburg	144	0.2	7.	Philadelphia	229	0.5
8.	Chicago	140	....	8.	Albany	191	12.3
9.	New Haven	135	....	9.	Chicago	190	3.3
10.	Philadelphia	132	0.3	10.	Washington	185	2.7
11.	Camden	131	Small	11.	Troy	183	4.2
12.	Paterson	128	Small	12.	Omaha	176	34.6
13.	Troy	125	3.9	13.	Jersey City	160	2.0
14.	Memphis	124	3.7	14.	St. Louis	159	6.3
15.	Wilmington	113	0.2	14.	Cleveland	159	4.9
16.	Cincinnati	112	4.1	15.	Grand Rapids	156	13.4
17.	Milwaukee	110	31.9	16.	New Haven	150	2.6
18.	Cleveland	103	5.8	17.	Detroit	146	10.0
19.	Jersey City	97	1.2	18.	Boston	143	5.5
20.	Baltimore	94	0.1	19.	Nashville	140	41.5
20.	Omaha	94	19.4	20.	Paterson	129	20.7
21.	Boston	80	5.0	21.	Memphis	125	8.3
22.	New York	79	20.2	22.	Cincinnati	121	7.6
23.	Columbus	78	6.4	23.	Toledo	119	50.3
24.	Newark	76	2.4	24.	New York	116	....
25.	Reading	75	0.1	25.	Syracuse	102	47.3
25.	Minneapolis	75	6.3	26.	Richmond	100	30.4
26.	Louisville	74	5.9	26.	Louisville	100	7.5
27.	Toledo	72	9.4	27.	Trenton	99	....
27.	Brooklyn	72	2.5	28.	Baltimore	97	1.5
27.	St. Louis	72	8.2	29.	Newark	94	21.9
28.	Indianapolis	71	7.6	30.	Minneapolis	93	27.5
28.	Kansas City	71	17.6	31.	Reading	92	4.0
29.	Syracuse	68	14.6	32.	Wilmington	90	4.3
30.	Lowell	66	22.9	33.	Lowell	85	52.5
30.	Rochester	66	11.4	34.	Atlanta	84	91.6
31.	Cambridge	64	2.4	35.	Rochester	83	25.3
32.	Trenton	62	Small	36.	Milwaukee	80	67.6
33.	San Francisco	61	41.4	37.	Cambridge	79	6.1
34.	St. Paul	60	4.2	37.	Indianapolis	79	6.0
35.	Worcester	59	89.4	38.	San Francisco	73	23.0
36.	Providence	48	62.4	39.	Worcester	70	94.3
37.	Dayton	47	3.8	40.	St. Paul	67	28.2
38.	New Orleans	37	0.4	41.	Kansas City	62	40.0
39.	Atlanta	36	89.6	42.	Dayton	62	46.7
40.	Fall River	29	74.6	43.	Providence	54	82.6
				44.	New Orleans	48	....
				45.	Fall River	36	94.3

* A few cities are omitted from each list, on account of missing figures. This table is based on Table I, which in turn was based on the classification of the census of 1890, instead of that of 1900.

† In Denver, water is used for irrigation.

against 18 in 1890, notwithstanding the marked increase in the use of meters in some of these cities. What the increase in the number of cities using more than 100 gallons a day would have been without the added percentage of meters, and what it might have been had meters been used more freely, one can only conjecture. Looked at another way, it may be seen, in the 1900 list, that of 18 cities having a consumption below 100 gallons per capita, 13 have over 20 per cent. of their taps metered.

It is gratifying to note that in more than half the cities shown in Mr. Bailey's Table I, the meters are furnished by the water department, and that in quite a number of additional cities the department supplies a part of them. As the practice of furnishing, setting, and repairing water meters by the department, rather than the consumer, increases, the public prejudice against meters will also decrease. The charging of meters, in liberal numbers, to capital account will diminish the capital account for reservoirs, pumps, and mains, and this saving will in most cases far more than offset the investment in meters.

PROCEEDINGS.

March Meeting.

Young's Hotel,
Boston, March 13, 1901.

President Crandall in the chair.

The following members and guests were in attendance: —

Members.

Charles H. Baldwin, Lewis M. Bancroft, Frank A. Barbour, Joseph E. Beals, James F. Bigelow, Dexter Brackett, Edwin C. Brooks, Fred Brooks, Walter I. Brown, James Burnie, George Cassell, George F. Chace, G. L. Chapin, John C. Chase, William F. Codd, Freeman C. Coffin, R. C. P. Coggeshall, Byron I. Cook, F. H. Crandall, Arthur W. Dean, A. O. Doane, Eben R. Dyer, Charles H. Eglee, Frank L. Fuller, Julius C. Gilbert, D. H. Gilderson, J. F. Gleason, Albert S. Glover, Amos A. Gould, Richard A. Hale, Frank E. Hall, John O. Hall, J. C. Hammond, Jr., George W. Harrington, T. G. Hazard, Jr., Horace G. Holden, John L. Howard, Willard Kent, Horace Kingman, Charles F. Knowlton, James W. Locke, A. E. Martin, William E. Maybury, Frank E. Merrill, Leonard Metcalf, Thomas Naylor, Frank L. Northrop, John H. Perkins, Dwight Porter, J. B. Putnam, A. H. Salisbury, Walter H. Sears, William T. Sedgwick, Edward M. Shedd, Charles W. Sherman, George H. Snell, George A. Stacy, Frederic P. Stearns, Charles N. Taylor, Lucian A. Taylor, Harry L. Thomas, Robert J. Thomas, William H. Thomas, D. N. Tower, George W. Travis, W. H. Vaughn, William W. Wade, Charles K. Walker, George E. Wilde, Frank B. Wilkins, George E. Winslow.

Associates.

Builders Iron Foundry, by Frederick N. Connet; Chapman Valve Co., by Edward F. Hughes; Charles A. Claflin & Co., by Charles A. Claflin; Coffin Valve Co., by H. L. Weston; George E. Gilchrist, by E. C. Jacobs; Hersey Mfg. Co., by Albert S. Glover; Henry F. Jenks; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Libbey, Parker & Co., by Henry N. Libbey; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey and J. L. Wertz; Perrin, Seamans & Co., by James C. Campbell; Sweet & Doyle, by Richard Hewins; Union Water Meter Co., by J. K. P. Otis,

Albert S. Otis, and Frank L. Northrop; United States Cast Iron Pipe & Foundry Co., by John M. Holmes.

GUESTS.

Macy S. Pope, Boston, Mass.; Henry Brown, Nantucket, Mass.; L. H. Pease, Member Water Board, New Bedford, Mass.; C. A. French, Superintendent of Streets, Marlboro, Mass.; H. A. Monk, Town Clerk, Braintree, Mass.; James I. Lairel, Plymouth, Mass.; Hamilton Flood, City Engineer, Quincy, Mass.; Fred Crosby, Montgomery, Ala.; Thomas Bell, St. John, N. B.; Dr. George W. Field, Massachusetts Institute of Technology, Boston, Mass.; I. T. Inman, Attleboro, Mass.; E. L. Dunning, Boston, Mass.; Fred J. Rourke, Purchasing Agent, and Michael J. Dowd, Water Commissioner. Lowell, Mass.; Walter E. Lord, Chairman Water Commissioners, Ipswich, Mass.; George Goodhue, Concord, Mass.; A. Plouff, Boston, Mass.

The Secretary read the names of the following applicants for membership, who were recommended for election by the Executive Committee: —

For Resident Member.

Dr. George W. Field, teacher of biology, Massachusetts Institute of Technology.

Hiram Allen Miller, Department Engineer, Metropolitan Water Works, Clinton, Mass.

Macy Stanton Pope, Inspector, Factory Mutual Insurance Co.'s, 31 Milk Street, Boston.

C. P. Moat, Chemist, Vermont State Board of Health, Burlington, Vt.

Dr. B. N. Stone, Biologist, Vermont State Board of Health, Burlington, Vt.

George D. Nash, Superintendent Winooski Aqueduct Co., Winooski, Vt.

John W. Moran, Superintendent Water Works, Gloucester, Mass.

On motion of Mr. Coggeshall, the Secretary was directed to cast the ballot of the Association in favor of the applicants, which he did, and they were declared elected.

The President called attention to hearings before the Committee on Water Supply of the Massachusetts Legislature on the 20th inst., upon bills regulating charges by private water companies or corporations, and to constitute the Board of Gas and Electric Light Commissioners the Board of Gas, Electric Light, and Water Commissioners, having supervision of private water companies.

THE JOURNAL.

Mr. C. W. Sherman.* I would like to say just a word, Mr. President, with reference to the annual reports. It is about the time when most of the superintendents are getting out their reports, and, as you all know, it is a part of the business of the Association to get together as far as possible the statistics given in these reports for publication in the Journal. I want to call the attention of the superintendents here present to this matter, and ask them to be sure to see to it that copies of their reports are sent to the Association headquarters.

We have prepared a blank form for the Summary of Statistics, so that it is only necessary to put in the figures in the proper places, and cross out the items not applicable to your particular works. These have been printed in such a manner that the leaves can be separated and used as part of the copy for the annual report; and I should be very glad to send copies to any one who will use them.

Mr. R. J. Thomas.† I would like to call the attention of the members present to the importance of consulting the advertising pages of the Journal when they are about to purchase supplies for their departments. It is probable that some of you do not realize the fact that a large proportion of our members depend upon the Journal for all the benefit that they get from this Association; the quarterly publication which they receive is the only return they get for their money. That is, of course, on account of the fact that they live so far from Boston it is inconvenient for them to attend our meetings.

Now, the success of the Journal depends to a large extent upon the revenues received from advertising; and the men dealing in supplies will not advertise in the Journal unless they find it is profitable for them to do so, and it rests with the members of this Association to make it pay these men to advertise. We have now about six hundred members, and if they will give the advertising patrons of the Journal a preference, or if they will at least consult them and obtain their figures on supplies when about to purchase, it would certainly be an object for every man in the water-works supplies line to have an advertisement in our Journal. There are many who do not advertise with us now, but who I have no doubt would

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* Editor, Journal of the New England Water Works Association.

† Advertising Agent, Journal of the New England Water Works Association.

be glad to avail themselves of the pages of the JOURNAL for reaching the members, providing the members would only bear them in mind and consult the advertising pages when they wanted anything in any special line. We want to get as many of the water-works supplies men to advertise in the JOURNAL as possible, and the assistance of all the members is requested to that end.

THE PRESIDENT. I think we can all appreciate the importance and value of what our advertising agent has just said, and we are no doubt all glad to do what we can in seconding his efforts to make the JOURNAL a financial success.

The President then opened the discussion upon the subject, "When Necessary to Assess the Annual Cost of Fire Protection upon the Parties Directly Benefited, how can the Assessment be most Equably Apportioned?" * The subject was further discussed by Messrs. Charles K. Walker, Macy S. Pope, J. Waldo Smith, F. N. Connet, J. C. Hammond, Jr., John C. Chase, Horace G. Holden, and Prof. William T. Sedgwick.

On motion of Mr. Byron I. Cook, a committee of five was appointed by the President to consider the subject further and to report at a future meeting. The President appointed as the committee: Messrs. Byron I. Cook, Edward V. French, J. C. Hammond, Jr., Charles K. Walker, and John C. Chase.

Dr. George W. Field, of the Massachusetts Institute of Technology, Boston, then gave an interesting talk on "Eels in Water Works and their Control." Questions were asked and experiences told by Messrs. D. H. Gilderson, George F. Chace, John C. Chase, J. C. Hammond, Jr., Harry L. Thomas, Charles W. Sherman, Leonard Metcalf, Richard A. Hale, Prof. William T. Sedgwick, George W. Travis, and others.

Adjourned.

*This is a continuation of the discussion began at the February meeting, under the title of "Charges for Private Fire Service."

OBITUARY NOTES.

Dr. Jo H. Linsley, who joined this Association March 8, 1899, died at Burlington, Vt., February 17, 1901.

Dr. Linsley was born in Windsor, May 29, 1859. He attended the public schools of Burlington, and graduated from the Medical Department of the University of Vermont in 1880. During his practice in Burlington the doctor filled the office of city physician and health officer for a number of years. In the course of his short but useful career Dr. Linsley served as instructor in clinical microscopy in the New York Post-Graduate Medical School and Hospital; director of the laboratories of histology, pathology, and bacteriology; pathologist to the New York Post-Graduate Hospital and the New York Infant Asylum; English secretary of the section for hygiene of the Tenth International Congress, held in Berlin, 1890; representative in Germany for the New York Post-Graduate School (during this period he took a course in bacteriology under Koch, and gave the first address on the lymph treatment for tuberculosis before the New York County Medical Society); professor of pathology and bacteriology at the University of Vermont; chairman on admission and ethics of the New York Pathological Society. He also was a writer and translator of several medical works.

The work for which he will be most remembered in Burlington, aside from the attractive qualities of his private life, was the establishing of the Vermont Laboratory of Hygiene, which opened in 1897 under his direction, with fittings from his private laboratory. It has grown to large proportions, and is now a regularly equipped State institution for the examination of infected water and food supplies and infectious diseases.

Dr. Linsley was an enthusiast in whatever he undertook, and will be sadly missed by a large circle of acquaintances and friends.

Patrick F. Crilly, superintendent of the Woburn, Mass., Water Works, died on Monday, March 25, 1901, at the Massachusetts General Hospital, after an unsuccessful operation.

Mr. Crilly was born in Louth, Ireland, about forty-six years ago.

He came to this country at the age of seventeen, and entered the employment of the late George H. Norman on water-works construction. In 1886 he became superintendent of the Woburn Water Works, and held this position until his death. He left a widow and two children.

Mr. Crilly became a member of this Association on March 12, 1890.

Henry W. Rogers, one of the founders of this Association, and its president in 1886–87, died on April 15, 1901, at the home of his sister in Haverhill, at the age of sixty-five.

He was born in Warren, Vt., and came to Boston at the age of twenty-one to begin as a pipe-layer on the Boston Gas Works. A few years later he began contracting for himself, and in 1869 went to Beverly, and was for two years occupied in that town and in Salem building water works. He was superintendent of the Salem works for a year, and then went to Lawrence, where he built the greater part of the water works, and where he remained as superintendent for eleven years. The two following years were spent in Maine, building water works at Dover, Waterville, and Calais, after which he returned to Salem, and later went to Milford. In 1892 he became superintendent of the Haverhill Water Works, and held this office for six years. He then went to Roxbury, where he was engaged in the coal business for a short time, but was soon forced to give up business by failing health. He then returned to Haverhill, and spent the remainder of his life there.

A year ago Mr. Rogers was much affected by the death of his wife, and from that time failed steadily until the end. He leaves one son.

Mr. Rogers was always very popular with those who knew him. He was quiet and unobtrusive, but of sterling worth. In his death the Association loses a valuable member.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XV. September, 1901. No. 5.

WATER WORKS STATISTICS FOR THE YEAR 1900, IN FORM ADOPTED BY THE NEW ENGLAND WATER WORKS ASSOCIATION.

COMPILED BY CHARLES W. SHERMAN, EDITOR, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

In preparing a table of statistics for 1900, the Editor has attempted, —

First, to secure reports from all places publishing a summary of statistics in the form adopted by this Association, or a modification or abridgment thereof.

Second, to obtain statistics in manuscript on the blank forms furnished by the Association, from as many places as possible where summaries are not published in the annual reports.

Third, to compile as complete summaries as possible from such other reports as were accessible, and which contained sufficient data to render it worth while.

In these attempts he has succeeded as follows : —

1. Reports were secured from all places publishing summaries of which the Editor has knowledge.

2. Statistics in manuscript were obtained from the following places: Boston, Cambridge, Chelsea, Essex Junction, Nantucket, Nashua, Quincy, and Somerville; and the Editor takes this opportunity to express his thanks to the gentlemen through whom these data were secured. It is worthy of notice that in this list are two works owned by private water companies, — those at Nantucket and Nashua.

3. More or less complete statistics for twenty other places have

been compiled by the Editor from their annual reports, and the names of these places are printed in italics in the following tabulation.

Duty. — The duty of the pumps is computed by the following formula : —

$$\text{Duty} = \frac{\text{Gallons pumped (6)} \times 8.34 \text{ (lbs.)} \times 100 \times \text{dynamic head (8)}}{\text{Total fuel consumed (5).}}$$

It therefore represents the *average* duty of all the pumps, when there are more than one.

New Column. — In Table V, Service Pipes, the Editor has added a new column, headed "Percentage of Taps Metered." The figures in this column have been obtained by dividing the total number of meters (column 26) by the total number of service taps in use (column 22) ; and while this method may not always give strictly accurate results, the percentages given are believed to be sufficiently near the truth for all practical purposes.

REFERENCES TO ADOPTION OF FORM OF SUMMARY AND TO COMPILATIONS OF STATISTICS.

The form employed for a summary of statistics was adopted by the Association at the fourth annual convention, June 18, 1885, following the recommendation of a committee consisting of Messrs. William R. Billings and R. C. P. Coggeshall. Their report, together with the ensuing discussion, is printed in the *Transactions* of this Association for the year 1885, pages 118–148. A later committee, consisting of Messrs. Desmond FitzGerald and Willard Kent, endorsed the form of summary and recommended that a large number of copies be printed for distribution ; their report may be found in Volume VIII of the JOURNAL, page 9.

Compilations of statistics prepared in this form may be found as follows : —

YEAR.	JOURNAL.	
1886	Vol. I, No. 4,	p. 29
1887	Vol. II, No. 4.	p. 28
1888 to 1892 inclusive	Vol. VII,	p. 225
1893	Vol. IX,	p. 127
1894	Vol. X,	p. 131
1895–96	Vol. XII,	p. 273
1897–99	Vol. XV,	p. 65
1900	Vol. XV,	p. 367

The various compilations include statistics for the following places and for the dates given: —

1. Albany, N. Y., 1900.*
2. Andover, Mass., 1900.*
3. Arlington, Mass., 1900.*
4. Atlantic City, N. J., 1898, 1900.
5. Attleboro, Mass., 1894–1900.
6. Bay City, Mich., 1886–87, 1893–96, 1900.
7. Billerica, Mass., 1899-1900.
8. Boston, Mass., 1886–94, 1897, 1900.†
9. Brockton, Mass., 1893–1900.
10. Burlington, Vt., 1886–1900.
11. Cambridge, Mass., 1900.†
12. Chelsea, Mass., 1900.†
13. Concord, N. H., 1895, 1898, 1900.
14. Dover, N. H., 1900.*
15. Erie, Pa., 1900.*
16. Essex Junc., Vt., 1900.†
17. Fall River, Mass., 1886–95, 1897–1900.
18. Fitchburg, Mass., 1886–92, 1894–1900.
19. Geneva, N. Y., 1900.*
20. Haverhill, Mass., 1900.*
21. Holyoke, Mass., 1886–92, 1897–98, 1900.
22. Hull, England, 1900.*
23. Ipswich, Mass., 1900.*
24. Keene, N. H., 1899–1900.
25. Leicester, Mass., 1900.*
26. Leominster, Mass., 1900.*
27. Lewiston, Me., 1900.*
28. Lowell, Mass., 1886, 1897–1900.
29. Lynn, Mass., 1888–98, 1900.
30. Madison, Wis., 1900.
31. Manchester, N. H., 1900.*
32. Marlboro, Mass., 1900.*
33. Metropolitan Water Works, Mass., 1900.
34. Middleboro, Mass., 1895–1900.
35. Minneapolis, Minn., 1900.
36. Nantucket, Mass., 1900.†
37. Nashua, N. H., 1900.†
38. New Bedford, Mass., 1886–1900.
39. New London, Conn., 1886–1900.
40. Newton, Mass., 1888–1900.
41. Oberlin, Ohio, 1893–1900.
42. Plymouth, Mass., 1886–1900.
43. Providence, R. I., 1897–1900.
44. Quincy, Mass., 1893, 1900.†
45. Reading, Mass., 1893, 1895–1900.
46. Salem, Mass., 1900.*
47. Sandusky, Ohio, 1886.
48. Schenectady, N. Y., 1886, 1900.*
49. Somerville, Mass., 1900.†
50. Springfield, Mass., 1886–1900.
51. Taunton, Mass., 1886–1900.
52. Toronto, Canada, 1893.
53. Trenton, N. J., 1886–87.
54. Troy, N. Y., 1886, 1888–93, 1897–99.
55. Waltham, Mass., 1886–1900.
56. Ware, Mass., 1886, 1888–92, 1900.
57. Watertown, Mass., 1900.*
58. Wellesley, Mass., 1888–93, 1898–1900.
59. Whitman, Mass., 1897–1900.
60. Wilmington, Del., 1900.*
61. Winchendon, Mass., 1900.*
62. Woburn, Mass., 1900.*
63. Woonsocket, R. I., 1886–1900.
64. Worcester, Mass., 1900.*
65. Yonkers, N. Y., 1893–96, 1900.*

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* Compiled by the Editor. † Manuscript Summary.

1900.—TABLE I.—GENERAL AND PUMPING STATISTICS.

Number.	Name of City or Town.	Date of Construction.	By whom Owned.	Source of Supply.	Mode of Supply.	1 Builders of Pumping Machinery.	2.—Description of Coal Used. a—b Kind.	c Size.	d Brand.	e Av. Price per Gross Ton.	f Per Cent. of Ash.	g Wood. Price per Cord.
1	*Albany, N. Y.* . .	. .	City.	Hudson River (filtered) and Storage Reservoirs.	Pumping and Gravity.	. . .	. . .	. .	. . .	. .	. .	. .
2	*Andover, Mass.* .	. .	Town.	. . .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
3	*Arlington, Mass.* .	. .	Town.	Metropolitan W.W.	. . .	. . .	. . .	. .	. . .	. .	. .	. .
4	Atlantic City, N. J.	1882	City.	Driven Wells and Absecon Creek.	Pumping.	Worthington, Gordon-Maxwell.	Bituminous.	Run of Mine.	. . .	$3 18	6.4	. .
		1888		5 Artesian Wells.	Pumping.	Smith-Vaile.	Anthracite.	Pea.	. . .	3 53	8.5	. .
5	Attleboro, Mass. .	1873	Town.	Large Well.	Pumping.	Deane, Barr.	Bituminous.	. .	Georges Creek, Clearfield.	. .	. .	. .
6	Bay City, Mich. . .	1872	City.	Saginaw Bay.	Pumping.	Holly.	Bituminous.	Slack.	Bay County.	1 53	. .	$0 50
7	Billerica, Mass. . .	1898	Town.	Driven Wells.	Pumping.	Barr.	Bituminous.	. .	Georges Creek.	. .	. .	. .
8	Boston, Mass. . .	1848	City.	Metropolitan W. W.	. . .	. . .	. . .	. .	. . .	. .	. .	. .
9	Brockton, Mass. .	1880	City.	Salisbury Brook.	Pumping.	Worthington, Holly.	. . .	. .	. . .	. .	. .	. .
10	Burlington, Vt. .	1867–68	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.	. .	Reynoldsville.	3 70	.	Mill Shavings.
11	Cambridge, Mass. .	. .	City.	Stony Brook.	Pumping.	. . .	. . .	. .	. . .	. .	. .	. .
12	Chelsea, Mass. . .	1867	City.	Metropolitan W. W.	. . .	. . .	. . .	. .	. . .	. .	. .	. .
13	Concord, N. H. . .	1872	City.	Penacook Lake.	Gravity and Pumping.	. . .	. . .	. .	Pocahontas.	. .	. .	. .
14	*Dover, N. H.* . .	. .	Town.	. . .	Pumping.	. . .	. . .	. .	. . .	. .	. .	. .
15	*Erie, Pa.*	1868	City.	Lake Erie.	Pumping.	Cornish, Holly, Worthington.	Bituminous.	Slack.	. . .	. .	. .	. .
16	Essex Junc., Vt. .	1900	Village.	Springs.	Gravity.	. . .	. . .	. .	. . .	. .	. .	. .

17	Fall River, Mass. .	1874	City.	Watuppa Lake.	Pumping.	Worthington, Davidson.	Bituminous.	. .	Georges Creek.	. .	. .	. .
18	Fitchburg, Mass. .	1873	City.	Storage Reservoirs.	Gravity.	. . .	. . .	. .	. . .	. .	. .	. .
19	*Geneva, N. Y.* . .	. .	City.	. . .	Pumping and Gravity.	. . .	. . .	. .	. . .	. .	. .	. .
20	*Haverhill, Mass.* .	. .	City.	Kenoza Lake.	Pumping.	. . .	. . .	. .	. . .	. .	. .	. .
21	Holyoke, Mass. . .	1873	City.	Lakes and Storage Reservoirs.	Gravity.	. . .	. . .	. .	. . .	. .	. .	. .
22	*Hull, England* . .	. .	City.	Deep Wells.	Pumping.	. . .	. . .	. .	. . .	. .	. .	. .
23	*Ipswich, Mass.* . .	1893	Town.	. . .	Pumping.	. . .	. . .	. .	. . .	. .	. .	. .
24	Keene, N. H. . .	1868	City.	Sylvan and Echo Lakes.	Gravity.	. . .	. . .	. .	. . .	. .	. .	. .
25	*Leicester, Mass.* .	. .	. .	. . .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
26	*Leominster, Mass.*	. .	. .	. . .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
27	*Lewiston, Me.* . .	. .	City.	Lake Auburn.	Pumping.	. . .	. . .	. .	. . .	. .	. .	. .
28	Lowell, Mass. . .	1870	City.	Driven Wells.	Pumping.	Blake, Barr, Morris, Worthington, Deane, Knowles.	Bituminous.	Broken.	Cumberland.	$4 60	. .	.
29	Lynn, Mass. . . .	1870	City.	Storage Reservoirs and Saugus River.	Pumping.	Morris, Loretz.	Bituminous.	. .	Georges Creek.	. .	. .	. .
30	Madison, Wis. . .	1881	City.	10 Artesian Wells.	Pumping.	. . .	Anthracite.	Pea.	. . .	4 39	. .	. .
31	*Manchester, N. H.*	. .	City.	Lake Massabesic.	. . .	Davidson, R. D. Wood & Co.	. . .	. .	. . .	. .	. .	. .
32	*Marlboro, Mass.* .	. .	City.	Lake Williams.	Pumping.	Blake, Barr, Worthington.	. . .	. .	. . .	. .	. .	. .
33	Metropolitan Water District, Mass. (excepting Newton and Hyde Park, and including Swampscott) . .	1848 1872–8 1895—	State of Massachusetts.	Lake Cochituate, Sudbury River, Nashua River.	32.4% Pumping. 67.6% Gravity.	*Chestnut*	*Hill High*	*Service*	*Pumping*	*Stati*	*on.*	
						Holly, Quintard,	Bituminous.	. .	Georges Creek, Loyal Hanna.	4 00	8.8	. .
						Allis.	Anthracite.	Ser'ngs.				
						Chestnut	*Hill Low*	*Service*	*Pumping*	*Stati*	*on.*	
						Holly.	Bituminous.	. .	Loyal Hanna.	4 50	9.2	. .

1900.—TABLE I., *Continued.*—GENERAL AND PUMPING STATISTICS.

Number.	Name of City or Town.	Date of Construction.	By whom Owned.	Source of Supply.	Mode of Supply.	1 Builders of Pumping Machinery.	2.—Description of Coal Used. a—b Kind.	c Size.	d Brand.	e Av. Price per Gross Ton.	f Per Cent. of Ash.	g Wood. Price Per Cord.
							Spot	*Pond*	*Pumping*	*Station.*		
	Metropolitan Water District.—*Continued.*	. .	. .	. . .	. . .	Blake, Holly.	Anthracite. Bit. and Anth.	. . Ser'ngs.	. . .	$4 72	12.3	. .
34	Middleboro, Mass. .	1885	Fire Dist.	Well near Nemasket River.	Pumping.	Deane.	Bituminous.	. .	Georges Creek. Pocahontas.	3 85 5 10	. . . .	. . . .
35	Minneapolis, Minn.	1868	City.	Mississippi River.	Pumping.	Various.	Sawdust & Water Power.	. .	. . .	. .	. .	. .
36	Nantucket, Mass. . .	. .	Wannacomet Water Co.	Wannacomet Pond.	Pumping.	Blake, Worthington, Fairbanks-Morse.	Bituminous.	. .	. . .	4 56	. .	. .
37	Nashua, N. H. . . .	1853	Pennichuck W. W. Co.	Pennichuck Springs.	Pumping.	Worthington, Snow, Holly.	Bituminous.	. .	Georges Creek.	4 75	7.3	. .
38	New Bedford, Mass.	1866	City.	Great and Little Quittacas Ponds.	Pumping.	Dickson Mfg. Co.	Bituminous.	. .	Poc'h'tas.	3 75 4 95	7.	$4 00
39	New London, Conn.	1872	City.	Lake Konomoc.	Gravity.		. . .	. .	. . .	. .	. .	. .
40	Newton, Mass. . . .	1876	City.	Collecting Gallery.	Pumping.	Blake, Worthington.	Bituminous.	Broken.	Georges Creek.	5 00	8. *	6 00
41	Oberlin, Ohio	1887	City.	Vermilion River.	Pumping.	Deane.	Bituminous.	Run of Mine.	Pocahontas.	3 69	. .	. .
42	Plymouth, Mass. . .	1855	Town.	Great and Little South Ponds, Lout Pond.	Gravity and Pumping.	Worthington.	Bituminous.	. .	Various.	5 00	. .	. .

43	Providence, R. I. . .	1870	City.	Pawtuxet River.	Pumping.	Worthington,	Bituminous.	. .	New River Georges Creek.	$4 15	. .	$4 50
						Corliss,	Bituminous.	. .	New River.	4 31	. .	4 50
						Holly.	Anthracite.	Egg.	Reading, Beaver Meadow.	5 04	. .	5 00
44	Quincy, Mass. . . .	. .	City.	Metropolitan W. W.	. . .	. . .	. . .	. .	. . .	. .	. .	. .
45	Reading, Mass. . . .	1890–91	Town.	Filter Gallery.	Pumping.	Blake.	Coke, Bit.	. .	Georges Creek.	4 60 5 40	. .	. .
46	*Salem, Mass.*	. .	City.	Storage Reservoirs.	Pumping.	. . .	. . .	. .	. . .	. .	12.5	. .
47	*Schenectady, N. Y.*	. .	City.	Filter Gallery.	Pumping.	Dean.	. . .	. .	. . .	. .	. .	. .
48	Somerville, Mass. .	1868	City.	Metropolitan W. W.	. . .	. . .	. . .	. .	. . .	. .	. .	. .
49	Springfield, Mass. .	1864	City.	Storage Reservoirs.	Gravity.	. . .	. . .	. .	. . .	. .	. .	. .
50	Taunton, Mass. . . .	1876	City.	Elder's and Assawompsett Ponds.	Pumping.	Holly, Allis.	Bituminous.	. .	Cumberland.	4 25 4 75	12.3 9.5	. . . .
51	Waltham, Mass. . .	1872	City.	Filter Basin.	Pumping.	Barr, Worthington.	Bituminous.	. .	Georges Creek, Sonman	4 85	10.	. .
52	Ware, Mass.	. .	Town.	Wells.	Pumping.	Dean.	. . .	. .	. . .	. .	. .	. .
53	*Watertown, Mass.*	1884	Town.	Metropolitan W. W.	. . .	. . .	. . .	. .	. . .	. .	. .	. .
54	Wellesley, Mass. . .	1884	Town.	Wells.	Pumping.	Blake.	Bituminous.	. .	Georges Creek, Puritan.	3 76	9.9	3 50
55	Whitman, Mass. . .	1883–84	Town.	Well.	Pumping.	Blake, Worthington.	. . .	. .	. . .	. .	. .	. .
56	*Wilmington, Del.* .	. .	City.	Brandywine Creek.	Pumping.	. . .	. . .	. .	. . .	. .	. .	. .
57	*Winchendon, Mass.*	. .	Town.	. . .	Pumping.	. . .	. . .	. .	. . .	. .	. .	. .
58	*Woburn, Mass.* . .	1873	City.	. . .	Pumping.	. . .	. . .	. .	. . .	. .	. .	. .
59	Woonsocket, R. I. .	1884	City.	Crook Falls Brook.	Pumping.	Worthington. Deane.	Bituminous.	. .	Clearfield. New River.	5 29	7.3	3 00
60	*Worcester, Mass.* .	. .	City.	Storage Reservoirs.	. . .	. . .	. . .	. .	. . .	. .	. .	. .
61	*Yonkers, N. Y.* . .	. .	City.	Storage Reservoirs and Tubular Wells.	Pumping.	. . .	. . .	. .	. . .	. .	. .	. .

* Estimated.

1900. — TABLE I., *Continued.* — PUMPING STATISTICS.

Number.	3 Coal Consumed for the Year. Lbs.	4 Lbs. of Wood ÷ 3 = equivalent Coal.	5 Total Fuel Consumed for the Year Lbs. (3) + (4).	6 Total Pumpage for the Year in gallons.	7 Average Static Head against which Pumps Work. Feet.	8 Average Dynamic Head against which Pumps Work. Feet.	9 Number of Gallons Pumped per Lb. of Fuel.	10 Duty in Foot-pounds per 100 Pounds of Coal. No Deductions.	11 Cost per Million Gallons Pumped into Reservoir, figured on Pumping Station Expenses.	12 Cost per Million Gallons raised 1 foot high, figured on Pumping Station Expenses.	13 Cost per Million Gallons Pumped into Reservoir, figured on Total Maint'nce (CC).	14 Cost per Million Gallons raised 1 foot high, figured on Total Mainte-n'ce (CC).
2	487 891	. .	. . .	148 618 936	. .	330	. .	83 767 750	. . .	. . .	. . .	. . .
4	2 693 222	. .	. . .	955 726 046	81 7	123 3	355	36 501 217	$10 14	. . .	$ 30 04	$0 264
	950 752	. .	. . .	148 662 947	119 5	119 5	156	15 518 455				
5	612 345	. .	. . .	165 174 450	. .	188 215	269	53 300 000	. . .	. . .	. . .	. . .
6	4 665 950	5 670	4 671 620	1 142 339 229	93	113	244	23 044 756	6 53	$0 0578	32 50	0 2875
7	247 000	. .	. . .	20 487 044	. .	. . .	114	21 559 031	. . .	. . .	. . .	. . .
9	441 001	. .	. . .	425 363 414	. .	43	965	. . .	. . .	. . .	. . .	. . .
10	. . .	. .	. . .	312 896 525	289	316	. .	. . .	26 17	0 08	114 55	0 366
11	3 866 975	. .	. . .	2 651 277 240	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
13	285 606	. .	. . .	142 772 165	. .	. . .	499	. . .	. . .	. . .	. . .	. . .
14	707 560	. .	. . .	258 258 044	. .	. . .	. .	40 000 000 [1]	. . .	. . .	. . .	. . .
15	11 800 000	. .	. . .	3 124 440 644	235 5	. . .	316	. . .	. . .	. . .	. . .	. . .
17	3 914 000	. .	. . .	1 388 776 336	186 2	. . .	317	. . .	12 77	. . .	102 34	. . .
19	1 758 046	. .	. . .	255 934 811	. .	240	170	29 100 000	21 75	. . .	. . .	. . .
20	. . .	. .	. . .	838 038 893	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
23	243 185	. .	. . .	39 444 884	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
27	. . .	. .	. . .	1 456 365 000	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
	Station I.											
28	2 982 990	2 400	2 985 390	2 042 066 140	156 1	163 9	685	93 489 048	6 53	0 0399	. . .	. . .
	Total.											
	10 684 561	. .	. . .	2 884 271 028	. .	. . .	275	. . .	. . .	. . .	. . .	. . .
29	593 700	. .	593 700	378 782 675	. .	167	638	88 780 036	7 02	0 042	85 10	0 51
	2 123 400	158	2 123 558	1 330 784 875	. .	167	626	87 265 319				
30	1 441 600	. .	. . .	306 637 454	223 8	242 4	212	47 530 839	38 43	0 159	. . .	. . .
32	. . .	. .	. . .	179 923 700	. .	. . .	. .	W 47 948 000 B 78 368 780	. . .	. . .	. . .	. . .

33	*Chestnut*	*Hill*	*High Service*	*Pumping Station.*								
	9 916 452	. .	. . .	15 027 410 000	. .	96 5	1 511	121 800 000	$ 3 03	$ 0 0314	. . .	. . .
	Chestnut	*Hill*	*Low Service*	*Pumping Station.*								
	3 779 657	. .	. . .	9 431 140 000	. .	51 8	2 495	109 380 000	1 68	0 032	. . .	. . .
	Spot Pond	*Pumping Station.*										
	2 621 559	. .	. . .	2 015 130 000	. .	125 6	768	80 400 000	5 40	0 043	. . .	. . .
34	563 440	. .	563 440	85 032 000	182	203	151	25 663 050	35 66	0 175	$ 91 55	$0 45
35	Sawdust. 63 672 000	. .	= 15 918 000	6 863 135 260	. .	. . .	. .	68 016 609	7 38	0 033	. . .	. . .
36	298 740	675[2]	. . .	45 710 040	88	100	131	11 145 620	58 38	0 58	124 80	1 25
37	1 547 000	. .	. . .	1 398 936 786	130	143	. .	. . .	4 20	. . .	23 70	. . .
38	2 834 275	129	2 834 404	2 307 429 372	167 2	192	814	130 336 508	4 98	0 0259	55 04	0 2867
40	2 225 166	6 000	2 231 166	762 876 073	234	254	334	72 500 000	12 72	0 05	150 25	0 59
41	282 000	. .	. . .	36 560 000	80	80	130	8 650 000	38 80	0 48	119 50	1 50
42	306 518	4 500	320 018	130 233 312	65	66	425	24 626 739	17 01	0 25	96 36	1 46
43	5 581 300	133	5 581 433	3 833 243 445	171 6	176 9	687	101 301 600	L. S. 4 59	0 0259	. . .	. . .
	72 800	750	73 550	34 401 038	172 4	177 7	473	69 329 100				
	877 631	563	878 194	578 940 480	111 2	124 7	660	68 533 300	H. S. 15 49	0 1134	. . .	. . .
45	435 560	. .	435 560	54 250 465	219	240	125	24 900 000	52 99	0 221	278 49	1 16
46	1 932 046	. .	. . .	985 252 640	. .	127	510	65 942 930	. . .	. . .	. . .	. . .
50	982 400	. .	982 400	591 294 779	. .	61 5	602	30 880 224	10 58	0 172	91 76	1 49
	415 200	. .	415 200	500 809 575	. .	. . .	. .	. . .				
51	1 270.655	. .	. . .	773 020 136	164	180	W 293 B 663	91 327 530	10 49	0 058	57 17	0 318
52	551 696	667	552 363	107 481 728	. .	244	194	39 579 333	. . .	. . .	75 70	. . .
54	477 100	317	477 417	87 194 763	250	278	183	42 121 882	26 56	0 095	199 42	0 717
55	412 019	. .	. . .	48 661 422	. .	. . .	. .	. . .	. . .	. . .	. . .	. . .
57	104 162	. .	. . .	20 542 416	. .	. . .	. .	43 314 734	. . .	. . .	. . .	. . .
58	. . .	. .	. . .	417 435 900	. .	216 2	271	. . .	. . .	. . .	. . .	. . .
59	1 334 200	335	1 334 535	340 849 628	237 6	239 5	255	51 024 641	14 70	0 061	88 45	0 37
61	6 148 225	. .	. . .	1 323 696 099	. .	. . .	216	. . .	. . .	. . .	. . .	. . .

[1] About. [2] Gallons Gasolene.

1900. — TABLE II. — FINANCIAL STATISTICS. — MAINTENANCE.

Number.	Name of City or Town.	Receipts from Consumers.						
		A	B	N	Q	C	D	E
		Rates. Domestic.	Rates. Manufacturing.	Fixture Rates.	Meter Rates.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts from Consumers.
2	*Andover, Mass.*	...	...	...	...	$ 10 668 47	$ 2 061 70	$ 12 730 17
3	*Arlington, Mass.*	...	...	...	...	30 523 37	...	...
4	Atlantic City, N. J.	...	...	...	...	81 500 65	13 745 80 [1]	...
5	Attleboro, Mass.	...	...	...	...	21 424 41	...	...
6	Bay City, Mich.	$ 18 194 91	$ 5 921 24	...	...	24 116 15	240 10	24 356 25
7	Billerica, Mass.	...	...	$ 1 405 80	$ 1 162 62	...	...	...
8	Boston, Mass.	...	...	...	...	2 198 078 93	361 948 10	2 560 027 03
9	Brockton, Mass.	...	...	8 396 06	58 468 06	66 864 12	6 517 80	73 381 92
10	Burlington, Vt.	38 239 01	3 953 21	9 689 17	39 404 29	42 192 22	1 914 69	44 106 91
11	Cambridge, Mass.	...	...	...	...	...	...	319 479 37
12	Chelsea, Mass.	64 572 81	14 925 91	...	...	79 498 72	4 237 63	83 736 35
13	Concord, N. H.	...	...	25 274 77	31 485 63	56 882 92	146 04	57 003 71
15	*Erie, Pa.*	...	...	99 047 99	22 411 31	121 459 30	3 019 73	124 477 03
16	Essex Junc., Vt.	650 00	...	...	...	650 00	600 00	1 250 00
17	Fall River, Mass.	...	...	...	...	163 896 19	4 736 97	168 633 16
18	Fitchburg, Mass.	50 833 90	17 638 50	22 941 75	45 530 65	68 472 40	4 542 51	73 014 91
19	*Geneva, N. Y.*	...	...	7 781 25	9 212 54	...	...	...
20	*Haverhill, Mass.*	...	...	...	...	97 185 73	7 123 30	104 309 03
21	Holyoke, Mass.	...	...	69 780 53	14 571 63	84 352 16	...	...
24	Keene, N. H.	...	...	...	...	34 499 72	...	...
25	*Leicester, Mass.*	...	...	...	...	4 966 58	1 163 46 [1]	...
26	*Leominster, Mass.*	...	...	27 493 42	8 575 90	36 069 32	1 878 53 [1]	...
28	Lowell, Mass.	...	...	...	...	210 149 93	...	...
29	Lynn, Mass.	121 280 58	73 558 75	...	...	194 839 33	13 983 70	208 823 03
31	*Manchester, N. H.*	...	...	...	...	119 441 75	375 19	119 816 94
32	*Marlboro, Mass.*	...	...	...	...	31 867 09	1 449 51	...

34	Middleboro, Mass.	. . .	. . .	$ 3 659 38	$ 7 067 70	$ 10 727 08	$ 318 52	$ 11 045 60
37	Nashua, N. H.	. . .	. . .	. . .	. . .	. . .	. . .	. . .
38	New Bedford, Mass.	$93 403 62	$10 367 84	. . .	. .	103 771 46	273 13	104 044 59
39	New London, Conn.	. . .	. . .	. . .	. . .	49 063 89	. . .	. .
40	Newton, Mass.	. . .	. . .	18 417 11	111 580 60	130 027 71	. . .	130 027 71
41	Oberlin, Ohio	5 098 97	246 00	. . .	. . .	5 314 97	499 22	5 844 19
42	Plymouth, Mass.	20 511 41	1 454 32	. . .	. . .	21 965 73	602 80	22 568 53
45	Reading, Mass.	8 465 64	114 63	. . .	. . .	8 580 27	339 92	8 920 19
46	*Salem, Mass.*	. . .	. . .	63 703 01	16 313 08	80 016 12	1 948 74	81 964 86
47	*Schenectady, N. Y.*	. . .	. . .	. . .	. . .	74 718 69	. . .	81 056 15
48	Somerville, Mass.	. . .	. . .	162 396 84	48 204 61	210 601 45	. . .	210 601 45
49	Springfield, Mass.	. . .	. . .	146 204 44	66 922 07	213 126 51	783 00	. . .
50	Taunton, Mass.	43 025 26	12 811 08	. . .	. . .	55 836 34	713 05	56 549 39
51	Waltham, Mass.	57 839 19	7 114 07	. . .	. . .	64 953 26	{ 2 959 93[1] { 2 353 90	70 267 09
52	Ware, Mass.	. . .	. . .	. . .	8 576 69	. . .	573 28	. . .
53	*Watertown, Mass.*	. . .	. . .	2 022 75	23 273 88	25 296 63	. . .	. . .
54	Wellesley, Mass.	12 556 34	189 48	. . .	. . .	12 745 82	1 519 83	14 265 65
55	Whitman, Mass.	5 989 13	622 16	2 453 82	4 157 47	6 611 29	739 01	7 350 30
57	*Winchendon, Mass.*	3 787 02	. . .	. . .	. . .	. . .	. . .	. . .
58	*Woburn, Mass.*	. . .	. . .	. . .	. . .	. . .	845 18	. . .
59	Woonsocket, R. I.	40 970 45	10 932 43	. . .	. . .	51 902 88	116 83	52 019 71
60	*Worcester, Mass.*	. . .	. . .	. . .	. . .	. . .	. . .	. . .
61	*Yonkers, N. Y.*	. . .	. . .	. . .	. . .	124 231 08	1 870 85	126 104 93

[1] Balance from previous year.

1900. — TABLE II., *Continued.* — FINANCIAL STATISTICS. — MAINTENANCE.

Number.	F. Receipts from Public Funds. Hydrants.	G. Fountains.	H. Street Watering.	I. Public Buildings.	J. General Appropriation or Miscellaneous.	Total from Public Funds.	K. Gross Receipts from All Sources.	AA. Expenditures. Management and Repairs.	BB. Interest on Bonds.	CC. Total Maintenance for the Year.	DD. Balance.	EE. Total.
2	. . .	. . .	. . .	. . .	. . .	. . .	. . .	$ 4 915 23	$ 6 000 00	. . .	. . .	. . .
3	. . .	. . .	. . .	. . .	. . .	. . .	$ 43 835 45	. . .	12 560 00	. . .	. . .	. . .
4	. . .	. . .	. . .	. . .	$ 2 800 00	. . .	123 246 45	41 549 27	44 015 00	. . .	$21 000 00[2] 13 887 99[3] 2 794 19	$123 246 45
5	. . .	. . .	. . .	. . .	6 000 00	. . .	27 424 41	9 238 39	13 183 44	$ 22 421 83	5 000 00[2] 2 58	27 424 41
6	. . .	. . .	. . .	. . .	22 390 00	. . .	46 746 25	14 739 19	22 390 00	37 129 19	9 617 06	46 746 25
7	$ 2 300 00	. . .	. . .	. . .	1 000 00	$ 3 300 00	5 984 90	2 006 56	3 600 00	5 606 56	378 34	5 984 90
8	. . .	. . .	. . .	. . .	161 724 47	. . .	2 721 751 50	1 085 860 92	805 924 26	. . .	. . .	. . .
9	3 000 00	. . .	$1 000 00	. . .	. . .	4 000 00	77 381 92	16 412 56	31 957 50	48 370 06	29 011 86[2]	77 381 92
10	3 540 00	$ 230 45[5]	2 056 34	$586 23[5]	488 22	6 901 24	51 008 15	26 280 82	9 920 00	36 200 82	12 296 58[2] 2 200 00[3] 310 75[4]	51 008 15
12	2 002 50	7 50	1 888 02	706 24	. . .	4 601 26	88 340 61	14 799 41	12 000 00	26 799 41	. . .	. . .
13	. . .	. . .	. . .	. . .	. . .	. . .	. . .	27 348 55	25 825 00	. . .	. . .	. . .
15	32 725 00	1 410 46	147 78	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
16	405 00	. . .	. . .	. . .	. . .	105 00	1 655 00	. . .	1 480 00	. . .	. . .	. . .
17	. . .	. . .	. . .	. . .	11 700 28	. . .	180 333 44	51 615 47	98 205 00	149 820 47	30 512 97	180 333 44
18	. . .	. . .	. . .	. . .	. . .	. . .	73 014 91	. . .	. . .	36 740 69[6]	36 274 22[4]	73 014 91
19	. . .	. . .	. . .	. . .	. . .	. . .	18 980 89	11 342 25	. . .	. . .	. . .	. . .
20	. . .	. . .	. . .	. . .	. . .	. . .	. . .	22 420 48	39 440 00	. . .	17 000 00[2]	. . .
21	. . .	. . .	. . .	. . .	. . .	. . .	182 767 79	27 499 29	18 500 00	45 999 29	13 567 50[2] 97 438 89[3]	. . .
24	5 375 00	350 00	1 200 00	175 00	. . .	7 100 00	30 599 72	2 019 61	3 095 00	5 144 61	25 455 11[4]	30 599 72
25	1 300 00	. . .	. . .	. . .	. . .	. . .	7 430 04	. . .	2 806 00	5 460 51	. . .	. . .
26	11 800 00	. . .	. . .	. . .	. . .	12 837 26	. . .	1 945 05	12 912 50	14 857 55	. . .	. . .
28	. . .	. . .	. . .	. . .	. . .	. . .	. . .	83 630 39	49 307 00	132 937 39	. . .	. . .
29	. . .	. . .	. . .	. . .	. . .	. . .	208 823 03	62 717 77	73 796 24	136 514 01	72 309 02[2]	208 823 03
31	18 425 00	. . .	. . .	. . .	. . .	. . .	138 241 94	31 419 27	39 534 50	. . .	. . .	. . .
32	6 760 00	. . .	. . .	. . .	. . .	. . .	40 076 60	. . .	. . .	. . .	. . .	. . .
34	. . .	. . .	. . .	. . .	3 778 03[1] 1 500 00	. . .	16 323 63	5 405 51	2 380 00	7 785 51	3 000 00[2] 2 608 03[3] 2 930 09	16 323 63

37	$ 7 230 00	$ 225 00	$ 700 00	$ 759 73	. . .	$ 8 214 73	. . .	. . .	. . .	. . .	. . .	. . .
38	. . .	. . .	. . .	. . .	$133 440 00	133 440 00	$237 484 59	$48 560 92	$ 78 440 00	$127 000 92	$28 000 00[2] 4 483 67[3] 78 000 00[7]	$237 484 59
39	10 320 00	150 00	4 000 00	400 00	. . .	. . .	63 933 89	9 055 34	14 915 00	23 970 04	39 963 85[3]	63 933 89
40	. . .	. . .	. . .	. . .	. . .	. . .	. . .	17 124 42	97 500 00	114 624 42	15 403 29	130 027 71
41	. . .	. . .	. . .	. . .	3 400 00	. . .	9 244 19	2 723 88	1 645 00	4 368 88	2 395 27[3] 2 480 04[2]	9 244 19
42	. . .	. . .	. . .	. . .	. . .	0	22 568 53	11 090 57	3 637 15	14 727 72	7 840 81	22 568 53
45	3 930 00	300 00	. . .	. . .	2 470 00	6 700 00	15 620 19	6 453 99	8 700 00	15 153 99	466 20	15 620 19
47	0	0	0	0	. . .	. . .	. . .	. . .	19 750 00	. . .	. . .	. . .
49	19 100 00	1 745 00	5 615 06	9 649 75	0	36 109 81	274 954 75	27 014 24	89 000 00	116 014 24	. . .	. . .
50	0	2 572 92	800 00	637 26	8 556 40	12 566 58	69 115 97	23 590 18	30 668 00	54 258 18	14 857 79[2]	69 115 97
51	. . .	. . .	. . .	. . .	. . .	. . .	70 267 09	27 780 33	16 415 00	44 195 33	22 028 16[2] 4 043 60	70 267 09
52	1 000 00	171 45	. . .	265 43	. .	. . .	10 859 39	. . .	. . .	7 875 99	1 500 00[3]	. . .
53	. . .	. . .	. . .	. . .	. . .	. . .	29 156 06	3 301 60	. . .	. . .	. . .	. . .
54	4 720 00	400 00	300 00	149 85	. . .	5 569 85	19 835 50	6 488 52	10 800 00	17 288 52	2 516 98	19 835 50
55	2 580 00	. . .	. . .	. . .	. . .	2 580 00	9 930 30	. . .	4 000 00	8 017 75	1 912 55[3]	9 930 30
57	3 600 00	200 00	167 82	. . .	. . .	. . .	7 772 81	. . .	3 840 00	5 861 37	1 911 44	7 772 81
58	1 730 00	. . .	. . .	. . .	. . .	. . .	44 201 44	13 450 68	5 725 38	. . .	25 025 38[2]	44 201 44
59	15 925 00	1 552 74	2 254 13	537 59	13 642 94	. . .	85 932 11	13 005 45	17 125 14	30 130 59	55 801 52	85 932 11
60	. . .	. . .	. . .	. . .	. . .	. . .	263 208 41	59 837 06	134 250 00	194 087 06	69 121 35[2]	. . .
61	21 840 00	. . .	. . .	. . .	. . .	. . .	147 944 93	47 579 67	76 950 00	124 529 67	29 379 20[2] —5 963 94[8]	147 944 93

[1] Balance from previous year. [2] To Sinking Fund. [3] To Construction Account. [4] To City Treasury. [5] Paid at Meter Rates. [6] Including *Construction.* [7] Bonds Paid. [8] Deficit.

1900.—TABLE II., *Continued.*—FINANCIAL STATISTICS.—CONSTRUCTION.

Number.	Name of City or Town.	Construction Receipts. R Balance from Previous Year.	S Bonds Issued.	T Appropriations from Tax Levy.	U Other Sources.	V Total.
1	*Albany, N. Y.*	. . .	. . .	. . .	. . .	. . .
2	*Andover, Mass.*	. . .	. . .	. . .	. . .	. . .
3	*Arlington, Mass*	. . .	. . .	. . .	. . .	. . .
4	Atlantic City, N. J.	. . .	. . .	. . .	{ $ 265 83 { 13 887 99 [1]	$ 14 153 82
5	Attleboro, Mass.	$ 9 116 26	$12 000 00	. . .	5 040 67	26 156 93
6	Bay City, Mich.	11 897 88	. . .	. . .	{ 91 81 { 9 617 06 [1]	21 606 75
7	Billerica, Mass.	684 71	. . .	. . .	1 793 86	2 478 57
8	Boston, Mass.	40 230 54	. . .	. . .	386 988 24 [1]	427 218 78
9	Brockton, Mass.	8 682 01	15 000 00	. . .	3 178 21	26 860 22
10	Burlington, Vt.	. . .	. . .	. . .	2 200 00 [1]	2 200 00
11	Cambridge, Mass.	. . .	. . .	. . .	. . .	. . .
12	Chelsea, Mass.	. . .	. . .	. . .	. . .	. . .
13	Concord, N. H.	. . .	. . .	. . .	. . .	. . .
16	Essex Junc., Vt.	. . .	25 000 00	$700 00	12 800 00	38 500 00
17	Fall River, Mass.	. . .	20 000 00	. . .	. . .	20 000 00
18	Fitchburg, Mass.	. . .	. . .	. . .	. . .	. . .
19	*Geneva, N. Y.*	. . .	. . .	. . .	. . .	. . .
20	*Haverhill, Mass.*	10 544 19	57 965 00	. . .	. . .	. . .
21	Holyoke, Mass.	. . .	. . .	. . .	97 438 89 [1]	97 438 89
25	*Leicester, Mass.*	. . .	. . .	. . .	. . .	243 44
26	*Leominster, Mass.*	. . .	. . .	. . .	. . .	. . .
28	Lowell, Mass.	. . .	. . .	. . .	. . .	. . .
29	Lynn, Mass.	8 572 16	50 000 00	. . .	3 466 41	62 038 57
30	Madison, Wis.	. . .	. . .	. . .	. . .	. . .
31	*Manchester, N. H.*	54 054 36	. . .	. . .	. . .	. . .

32	*Marlboro, Mass.*	. . .	. . .	. . .	. . .	. . .
34	Middleboro, Mass.	. . .	. . .	. . .	$2 608 03[1] 1 641 53	$ 4 249 56
38	New Bedford, Mass.	$12 836 92	. . .	. . .	4 483 67[1] 8 280 38	25 600 97
39	New London, Conn.	34 446 64	. . .	. . .	39 963 85[1]	74 410 49
40	Newton, Mass.	. . .	. . .	. . .	28 050 50	28 050 50
41	Oberlin, Ohio	497 74	. . .	. . .	2 395 27[1] 290 25	3 483 26
42	Plymouth, Mass.	6 620 59	$30 621 00	. . .	1 200 81[1]	38 442 40
43	Providence, R. I.	. . .	. . .	. . .	. . .	. . .
44	Quincy, Mass.	. . .	30 000 00	. . .	16 646 58	46 646 58
45	Reading, Mass.	1 233 18	11 439 00	. . .	466 20[1] 870 32	14 008 70
46	*Salem, Mass.*	. . .	. . .	. . .	. . .	. . .
47	*Schenectady, N. Y.*	. . .	. . .	. . .	. . .	. . .
48	Somerville, Mass.	. . .	. . .	. . .	. . .	. . .
49	Springfield, Mass.	392 27	. . .	. . .	12 983 07[1] 3 323 95	16 699 29
50	Taunton, Mass.	6 970 20	55 000 00	. . .	5 398 43	67 368 63
51	Waltham, Mass.	212 58	. . .	$20 000 00	2 549 95	22 762 53
52	Ware, Mass.	125 35	. . .	2 700 00	1 500 00[1]	4 325 35
53	*Watertown, Mass.*	. . .	. . .	. . .	. . .	. . .
54	Wellesley, Mass.	545 15	12 000 00	. . .	867 85	13 413 00
55	Whitman, Mass.	2 817 58	. . .	. . .	96 23[1] 1 912 55	4 826 36
57	*Winchendon, Mass.*	. . .	. . .	. . .	. . .	. . .
58	*Woburn, Mass.*	. . .	. . .	. . .	. . .	. . .
59	Woonsocket, R. I.	. . .	. . .	5 514 77	3 702 70	9 217 47
61	*Yonkers, N. Y.*	. . .	25 000 00	. . .	. . .	. . .

[1] From Maintenance Account.

1900. — TABLE II., *Concluded.* — FINANCIAL STATISTICS. — CONSTRUCTION AND MISCELLANEOUS.

Number.	Construction Expenditures.						Miscellaneous.			
	FF	GG	HH	II	JJ	KK	W	X	Y	Z
	Extensions.		Special.	Total Cost of Construction for the Year.	Balance.	Total.	Net Cost of Works to Date.	Bonded Debt at Date.	Value of Sinking Fund at Date.	Rate of Interest, Per Cent.
	Mains.	Services.								
1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	$ 1 739 000 00	. . .	3.5 to 7
2	. . .	. . .	. . .	$ 3 485 69	. . .	. . .	$ 208 624 48	145 000 00	$ 9 296 16	. . .
3	$ 13 056 90	$ 1 014 60	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
4	9 277 90	. . .	$ 4 875 92	14 153 82	. . .	. . .	916 723 59	892 000 00	100 407 01	4.5 to 5
5	. . .	. . .	. . .	26 156 93	0	$ 26 156 93	374 488 18	305 000 00	62 430 10	. . .
6	9 726 39	. . .	645 15[1]	10 371 54	$11 235 21	21 606 75	598 082 21	352 000 00	. . .	av. 6.25
7	. . .	. . .	. . .	2 433 16	45 41	2 478 57	91 705 87	90 000 00	. . .	. . .
8	324 395 11	40 208 95	. . .	364 604 06	62 614 72	427 218 78	23 054 387 81	11 960 273 98	10 144 647 08	3.5 to 6
9	16 161 01	. . .	6 587 75	22 748 76	4 111 46	26 860 22	913 211 06	777 000 00	317 925 96	4
10	1 660 04	539 96	. . .	2 200 00	0	2 200 00	468 039 73	248 000 00	61 076 40	3.5 to 4
11	. . .	. . .	. . .	. . .	. . .	. . .	5 670 229 52	3 302 100 00	604 326 58	. . .
12	3 292 49	. . .	. . .	3 292 49	. . .	. . .	483 335 52	300 000 00	50 921 00	4
13	. . .	. . .	. . .	. . .	. . .	. . .	857 440 98	650 000 00	. . .	. . .
16	. . .	. . .	. . .	38 500 00	. . .	. . .	38 500 00	25 000 00	0	4
17	19 942 45	. . .	. . .	19 942 45	57 55	20 000 00	1 937 862 93	1 920 000 00	581 647 78	5.1
18	. . .	. . .	. . .	. . .	. . .	. . .	452 091 09	648 000 00	195 908 91	. . .
19	. . .	. . .	. . .	7 313 30	. . .	. . .	181 628 73	. . .	. . .	. . .
20	8 221 75	2 879 63	32 604 26	43 705 64	. . .	. . .	1 300 142 54	1 006 000 00	142 596 03	4
21	51 641 02	1 331 51	. . .	97 438 89	0	97 438 89	1 244 742 23	300 000 00	37 403 46	4
25	. . .	. . .	. . .	555 08	. . .	. . .	81 002 87	70 000 00	8 376 42	. . .

26	. . .	. . .	. . .	. . .	. . .	. . .	$ 519 215 43	$ 292 000 00	. . .	. . .
28	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1 274 700 00	$287 226 20	. . .
29	$ 7 346 71	$6 611 49	$34 768 63	$48 726 87	$13 311 70	$62 038 57	2 472 821 85	1 800 300 00	521 027 50	3.5 to 5
30	. . .	. . .	. . .	. . .	. . .	. . .	337 360 13	. . .	. . .	. . .
31	1 224 81	1 624 58	. . .	12 981 61	. . .	. . .	1 513 012 79	900 000 00	159 466 83	4 to 6
32	. . .	. . .	. . .	. . .	5 046 87	. . .	586 261 13	538 000 00	150 055 96	. . .
34	3 326 33	923 23	. . .	4 249 56	0	4 249 56	116 420 15	57 500 00	6 376 61	4
38	11 026 35	8 779 60	. . .	19 805 95	5 795 02	25 600 97	1 820 107 73	558 000 00	148 793 77	av. 4.44
39	11 557 41	1 359 86	2 205 11	15 122 38	59 288 11	74 410 49	706 978 41	410 000 00	. . .	3.5 to 4
40	. . .	. . .	. . .	28 050 50	0	28 050 50	2 034 808 07	2 075 000 00	849 115 40	av. 4.7
41	14 16	1 276 80	1 500 00	. . .	391 80	3 183 26	86 381 42	48 000 00	2 570 10	3.5 to 5.75
42	40 359 53	342 80	5 588 01	46 290 34	—7 847 94 [2]	38 442 40	313 189 09	105 960 00	. . .	4
43	. . .	. . .	. . .	. . .	. . .	. . .	6 470 093 35	5 920 000 00	713 431 62	av. 3.7
44	. . .	. . .	. . .	45 831 85	814 73	46 646 58	. . .	720 500 00	. . .	4
45	11 483 58	1 720 31	755 88	13 959 77	48 93	14 008 70	265 462 18	219 000 00	. . .	4
46	. . .	. . .	. . .	4 446 00	. . .	. . .	1 917 590 39	. . .	. . .	. .
47	. . .	. . .	. . .	. . .	. . .	. . .	. . .	512 000 00	110 754 66	3 to 4
48	. . .	. . .	. . .	. . .	. . .	. . .	766 484 63	207 000 00	0 [3]	4 to 4.5
49	6 362 20	. . .	9 944 82	16 307 02	. . .	. . .	2 128 559 56	1 500 000 00	461 861 90	av. 5.9
50	10 981 42	4 744 37	13 299 33	29 025 12	38 343 51	67 368 63	1 243 185 49	812 000 00	174 628 88	4
51	. . .	. . .	. . .	17 172 04	5 590 49	22 762 53	614 000 00 [4]	426 000 00	98 407 17	3.5 to 4
52	. . .	. . .	. . .	4 247 41	77 91	4 325 35	131 090 08	41 400 00	. . .	3.5 to 4
53	. . .	. . .	. . .	8 966 14	. . .	. . .	309 169 56	. . .	. . .	. . .
54	8 703 64	1 252 04	2 174 19	12 129 87	1 283 13	13 413 00	322 718 24	278 000 00	82 790 82	4
55	. . .	. . .	. . .	2 351 08	2 475 28	4 826 36	129 632 93	100 000 00	31 894 51	4
57	1 996 42	. . .	. . .	. . .	. . .	. .	111 533 03	. . .	. . .	. . .
58	2 104 21	1 446 89	. . .	. . .	. . .	. . .	597 049 14	. . .	. . .	. . .
59	. . .	. . .	. . .	5 514 77	. . .	. . .	390 841 78	. . .	. . .	. . .
61	. . .	. . .	. . .	28 026 46	. . .	. . .	1 577 105 15	1 47 , 000 00	310 700 00	3.5 to 7

[1] For Extension of Meters. [2] Deficit. [3] Maturing bonds paid from income. [4] Total bonds issued to date.

1900.—TABLE III.—STATISTICS OF CONSUMPTION OF WATER.

Number.	Name of City or Town.	1	2	3	4	5	6		7	8	9	10
		Estimated Population.							Average Consumption. (Gallons per Day.)			
		Total at Date.	On Line of Pipe.	Supplied at Date.	Total Consumption for the Year. (Gallons.)	Quantity Used through Domestic Meters. (Gallons.)	Quantity Used through Manufacturing Meters. (Gallons.)	Percentage of Total Consumption Metered.	Total.	To Each Inhabitant.	To Each Consumer.	To Each Tap.
1	*Albany, N. Y.*	...	..	95 000	4 940 919 000 [1]	...	...	..	18 099 000	..	191	..
2	*Andover, Mass.*	6 813	..	..	148 618 936	...	...	..	407 172	60	..	..
3	*Arlington, Mass.*	8 603	..	..	...	...	...	..	297 400 [2]	..	..	634 [2]
4	Atlantic City, N. J.	28 000	27 500	150 000 [3]	1 104 388 993	...	...	..	...	..	..	737
5	Attleboro, Mass.	11 335	10 000	..	165 174 450	...	...	..	452 532	39	45	..
6	Bay City, Mich.	28 000	20 000	16 000	1 142 339 229	70 440 246	174 634 975	21	3 129 697	112	196	1 425
7	Billerica, Mass.	2 780	1 800	1 230	20 487 044	...	...	..	56 139	20	46	..
8	Boston, Mass.	560 892	..	..	...	...	...	..	...	..	..	..
9	Brockton, Mass.	40 063	37 000	35 000	425 362 414	159 944 862	58 234 260	51	1 165 376	29	33	221
10	Burlington, Vt.	18 800	18 300	18 100	312 896 525	140 045 612	27 797 250	53	857 250	46	47	256
11	Cambridge, Mass.	91 886	..	..	2 651 277 240	...	...	..	7 263 773	79	..	..
12	Chelsea, Mass.	34 000	34 000	34 000	1 095 000 000	21 539 205	110 415 517	12	3 000 000	87	87	488
13	Concord, N. H.	19 632	17 000	..	...	...	...	..	...	..	..	..
15	*Erie, Pa.*	52 733	..	..	3 124 440 644	...	...	..	8 560 111	162	..	..
16	Essex Junc., Vt.	1 125	800	500	...	...	...	..	...	..	..	..
17	Fall River, Mass.	107 623	..	104 523	1 388 776 336	...	...	..	3 804 867	35	36	..
18	Fitchburg, Mass.	31 531	..	27 000	1 022 000 000 [4]	...	...	..	2 800 000 [4]	..	103 [4]	..
19	*Geneva, N. Y.*	11 000	..	..	328 000 000 [4]	79 504 100		24	...	81	..	..
20	*Haverhill, Mass.*	37 175	..	..	838 038 893	...	...	..	2 268 868	61	..	..
21	Holyoke, Mass.	46 204	45 701	45 204	1 733 750 000 [4]	238 276 500		14	4 750 000 [4]	103	105	1 321
22	*Hull, England*	...	..	242 000	4 020 000 000	...	...	22	11 010 000	..	46	..
23	*Ipswich, Mass.*	4 658	..	..	39 444 884	...	...	..	109 164	23	..	..
24	Keene, N. H.	9 300	8 600	8 000	509 175 000 [4]	...	...	..	1 395 000 [4]	150	174	808
25	*Leicester, Mass.*	1 398	..	..	14 966 850 [5]	...	2 111 550 [5]	..	82 230	..	59	..
26	*Leominster, Mass.*	12 392	..	..	...	...	...	..	...	..	..	..
27	*Lewiston, Me.*	...	..	..	1 456 365 000	...	...	..	3 990 041	..	..	..
28	Lowell, Mass.	95 000	..	..	2 881 074 794	...	...	..	7 892 356	83	..	..
29	Lynn, Mass.	73 600	..	72 128	1 708 153 070	310 000 000		20	4 679 871	..	65	..
30	Madison, Wis.	19 164	..	16 548	306 637 450	...	...	..	837 332	44	51	304

32	*Marlboro, Mass.*	13 609	. .	11 726	179 921 700	. . .	. . .	. .	492 936	36	42	. .
33	Metropolitan W. W., Mass.	815 400	. .	. .	34 384 860 000	. . .	. . .	. .	94 205 000	116	. .	. .
34	Middleboro, Mass.	{ Town. 6 900 } { F.Dist. 4 240 }	4 000	3 750	85 032 000	15 861 135	25 240 659	48	232 964	56	62	284
35	Minneapolis, Minn. . . .	202 718	100 000	95 000	6 863 135 200	1 307 263 847		19	18 803 110	93	198	. .
36	Nantucket, Mass.	3 002	2 000	2 400 [3]	45 710 040	. . .	. . .	. .	125 233	42	52	134
37	Nashua, N. H.	25 000	24 000	23 900	1 398 936 786	. . .	. . .	. .	3 832 704	153	119	. .
38	New Bedford, Mass. . . .	62 500	56 000	55 000	2 306 997 774	137 369 250	402 103 500	23	6 320 542	101	115	681
39	New London, Conn. . . .	17 500	16 500	15 800	578 800 000 [4]	. . .	. . .	. .	1 585 770	91	100	514
40	Newton, Mass.	33 587	33 000	32 800	761 526 510	351 000 000	68 000 000	55	2 086 374	62	64	294
41	Oberlin, Ohio	4 800	3 600	2 800	36 560 000	14 500 000	1 220 000	43	100 000	21	36	160
42	Plymouth, Mass.	9 592	. .	. .	148 618 936	. . .	. . .	. .	407 172	43	. .	. .
43	Providence, R. I.	187 297	187 297	187 297	3 697 993 447	. . .	. . .	60 [4]	10 131 489	54	54	470
44	Quincy, Mass.	23 896	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
45	Reading, Mass.	4 969	4 550	4 200	54 250 465	. . .	. . .	. .	148 631	30	35	141
46	*Salem, Mass.*	35 956	. .	. .	985 252 640	. . .	. . .	. .	2 577 000	72	. .	. .
47	*Schenectady, N. Y.* . . .	32 000	. .	7 050	. . .	. . .	. . .	. .	. . .	. .	166	. .
48	Somerville, Mass.	62 500	62 500	62 500	. . .	. . .	. . .	. .	. . .	. .	. .	. .
49	Springfield, Mass.	62 059	53 000	48 200	1 997 097 500 [4]	425 004 191		21	5 471 500 [4]	88 [4]	114 [4]	560 [4]
50	Taunton, Mass.	31 006	28 000	26 116	591 294 779	80 894 819	140 636 896	37	1 619 985	53	62	359
51	Waltham, Mass.	23 700	23 300	23 250	773 020 136	37 024 278		5	2 117 863	90	92	644
52	Ware, Mass.	8 263	. .	. .	107 481 728	59 778 287		56	294 471	36	. .	. .
53	*Watertown, Mass.* . . .	9 706	. .	. .	. . .	. . .	. . .	. .	. . .	. .	. .	. .
54	Wellesley, Mass.	5 072	4 967	4 929	87 194 763	45 821 571	457 700	53	238 884	47	48	270
55	Whitman, Mass.	6 172	. .	. .	48 661 422	. . .	. . .	. .	133 318	22	. .	. .
56	*Wilmington, Del.*	76 500	. .	. .	2 529 322 860	1 016 936 250		40	. . .	90	. .	. .
57	*Winchendon, Mass.* . . .	5 001	. .	. .	20 542 416	9 696 750		47	57 835	12	28	154
58	*Woburn, Mass.*	14 254	. .	. .	417 435 900	42 572 170		10	1 116 811	80	. .	. .
59	Woonsocket, R. I.	32 500	32 000	32 000	341 074 454	. . .	. . .	. .	933 244	28	29	397
60	*Worcester, Mass.*	118 421	. .	113 217	2 890 601 107	1 489 290 945		52	7 919 455	. .	70	. .
61	*Yonkers, N. Y.*	. . .	. .	. .	1 323 696 099	. . .	. . .	48	3 626 564	76	. .	. .

[1] Nine months. [2] High service only. [3] Estimated average, including summer population. [4] Estimated. [5] Six months.

1900. — TABLE IV. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — MAIN PIPES.

Number.	Name of City or Town.	1 Kind of Pipe.	2 Size of Pipe. (Inches.)	3 Length Extended During the Year. (Feet.)	4 Length Discontinued During the Year. (Feet.)	5 Total Length in Use. (Miles.)	6 Cost of Repairs per Mile.	7 Number of Leaks per Mile.	8 Length of Pipe Less than 4 In. Diam. (Miles.)	9 Hydrants. Number Added.	10 Hydrants. Total in Use.	11 Gates. Number Added.	12 Gates. Total in Use.	13 Gates. Number less than 4 Inch.	14 Gates. Number of Blow-off Gates.	15 Range of Pressure on Mains at Center. (Pounds.)
1	*Albany, N. Y.*	. . .	. .	1 683	. .	129 7	. .	. .	. .	5	808	3	803	. .	. .	. . .
2	*Andover, Mass.*	. . .	. .	2 637	. .	25 8	. .	. .	. .	2	196	9	. .	. .	. .	. . .
3	*Arlington, Mass.*	C. I., C. L.	4 – 12	9 754	. .	33 1	. .	. .	0 7	21	326	24	265	. .	. .	. . .
4	Atlantic City, N. J.	C. I.	4 – 20	12 988	1 478	47 6	. .	. .	2 4	51	519	. .	. .	. .	9	. . .
5	Attleboro, Mass.	W. I., C. L., C. I.	1 – 16	5 278	. .	31 6	. .	0 57	. .	12	263	. .	. .	. .	. .	54– 62
6	Bay City, Mich.	C. I., Wyckoff.	3 – 20	10 597	6 349	45 3	$17 32	1 38	0 1	7	413	15	706	3	15	35– 38
7	Billerica, Mass.	C. L.	. .	. .	. .	9 7	. .	0 41	. .	. .	101	. .	84	. .	. .	54–120
8	Boston, Mass.	C. I.	2 – 48	52 949	59 085 [1]	713 4	27 09	0 5	2 1	122	7 606	239	8 910	10	. .	40– 90
9	Brockton, Mass.	W. I., C. L., C. I.	6 – 30	6 987	0	64 5	0 96	0 2	. .	16	608	21	628	. .	22	47– 56
10	Burlington, Vt.	C. L., C. I., W. I.	4 – 30	7 077	3 488	38 0	4 61	0 36	2 7	0	213	23	618	59	12	70– 85
11	Cambridge, Mass.	. . .	. .	9 586	. .	. .	. .	. .	. .	23	968	40	. .	. .	. .	. . .
12	Chelsea, Mass.	C. I.	6 – 16	1 728	0	37 8	. .	. .	0 1	6	253	5	399	0	30	48– 50
13	Concord, N. H.	C. I., C. L.	4 – 30	7 530	3 551	60 2	. .	. .	. .	4	267	16	757	. .	. .	. . .
14	*Dover, N. H.*	. . .	. .	. .	. .	. .	. .	. .	. .	0	176	. .	. .	. .	. .	. . .
15	*Erie, Pa.*	. . .	¾ – 20	18 799	. .	107 2	. .	. .	. .	28	595	95	. .	. .	. .	. . .
16	Essex Junc., Vt.	C. I.	4 – 10	22 000	0	4 2	. .	. .	. .	27	27	15	15	0	5	56– 59
17	Fall River, Mass.	C. I.	6 – 24	. .	. .	87 3	. .	. .	. .	20	954	16	940	. .	. .	80
18	Fitchburg, Mass.	C. I.	2 – 20	6 481	. .	66 6	. .	. .	. .	23	499	12	554	. .	. .	{ 75 L S 155 H S
19	*Geneva, N. Y.*	C. I.	2 – 16	4 172	. .	27 1	. .	. .	. .	15	207	10	250	3	. .	. . .
20	*Haverhill, Mass.*	. . .	2 – 24	9 360	. .	. .	. .	. .	. .	3	322	28	770	. .	. .	. . .
21	Holyoke, Mass.	C. I., W. I.	½ – 30	13 476	0	81 6	5 14	0 01	5 9	10	860	34	734	3	30	80–100
22	*Hull, England.*	. . .	. .	61 292	. .	208 0	. .	. .	. .	169	. .	. .	. .	. .	. .	. . .
23	*Ipswich, Mass.*	. . .	6 – 14	10 438	. .	14 9	. .	0 13	. .	11	137	. .	135	. .	. .	. . .
24	Keene, N. H.	W. I., C. L., C. I.	4 – 24	1 738	0	35 6	3 25	1 5	3 3	1	215	1	358	. .	27	45– 62
26	*Leominster, Mass.*	C. L., C. I.	1½ – 20	11 232	. .	46 1	. .	. .	. .	18	326	30	363	. .	. .	. . .
27	*Lewiston, Me.*	. . .	. .	. .	. .	. .	. .	. .	. .	1	173	5	. .	. .	. .	50–110
28	Lowell, Mass.	. . .	. .	8 011	. .	127 8	. .	. .	. .	10	1 098	22	1 188	. .	. .	. . .
29	Lynn, Mass.	W. I., C. L., C. I.	2 – 20	8 205	. .	129 4	. .	0 8	. .	8	952	12	966	. .	. .	45– 60
30	Madison, Wis.	C. I.	4 – 16	. .	. .	34 3	. .	. .	. .	. .	169	. .	231	. .	. .	. . .
31	*Manchester, N. H.*	C. L., C. I.	4 – 20	10 032	. .	96 9	. .	. .	. .	6	743	26	910	. .	. .	. . .
32	*Marlboro, Mass.*	. . .	4 – 16	0	. .	37 3	. .	0 05	1 4	. .	343	. .	386	. .	. .	. . .

33	Metropolitan W. W.															
	(Owned by Met. W.W.)	C. I., C. L.	6 – 60	13 140	. .	69 8	. .	. .	. .	. .	. .	28	268	. .	. .	
	(Tot.Sup.by Met.W.W.)	C. I., C. L., Kal.	4 – 60	164 000	. .	1 360 3	. .	. .	. .	297	11 913	. .	. .	. .	. .	. . .
34	Middleboro, Mass.	C. I.	4 – 12	4 376	. .	17 0	. .	0	. .	6	120	12	174	. .	6	45– 60
35	Minneapolis, Minn.	C. I., Steel.	1¼ – 50	42 219	0	269 2	. .	0 12	. .	106	3 172	106	2 195	. .	13	. . .
36	Nantucket, Mass.	C. I.	2 – 8	510	0	7 5	$ 0	0	5 3	0	50	3	66	. .	. .	. . .
38	New Bedford, Mass.	C. I.	4 – 36	12 315	1 061	92 7	24 00	0 16	1 2	15	738	38	1 065	80	95	28– 64
39	New London, Conn.	W. I., C.L., C. I.	4 – 24	8 918	0	50 5	18 71	0 48	3 1	15	258	11	318	. .	30	40– 48
40	Newton, Mass.	C. I.	4 – 20	7 071	700	136 6	6 43	0 04	2 9	5	935	11	801	47	380	84
41	Oberlin, Ohio	C. I.	4 – 12	0	0	9 3	0	0	0 3	0	87	1	57	2	2	27– 32
42	Plymouth, Mass.	C. L., W. I.	2 – 20	6 932	300	37 3	10 87	2	9	2	132	15	349	135	22	
43	Providence, R. I.	C. I.	6 – 36	36 185	3 830	324 6	0 56	0 07	0	32	1 886	68	3 399	0	32	64– 73
	H. P. Fire System	C. I.	12 – 24	. .	. .	5 6	. .	. .	. .	0	92	. .	31	. .	4	114
44	Quincy, Mass.	C. I., Kalamine.	2 – 20	28 100	1 900	84 1	. .	. .	7 1	50	539	82	1 001	. .	. .	78– 85
45	Reading, Mass.	C. I.	4 – 12	12 114	0	26 9	0 30	0 04	0	9	140	14	234	0	14	68– 78
47	*Schenectady, N. Y.*	. . .	4 – 12	15 124	. .	40 0	. .	. .	. .	48	469	38	710	. .	. .	
48	Somerville, Mass.	C. I., C. L.	4 – 20	14 048	. .	. .	3 77	0 2	. .	27 [2]	897 [2]	69	1 203	. .	108	45– 95
49	Springfield, Mass.	W. I., C. L., C. I.	1 – 36	12 837	5 015	144 7	5 50	0 30	7 7	2	955 [2]	52	1 889	361	89	30– 35 L S 100–120 H S
50	Taunton, Mass.	C. I.	4 – 20	6 240	. .	78 3	25 94	0 19	1 9	13	783	7	547	12	54	45
51	Waltham, Mass.	C. I., W. I., C. L.	2 – 24	5 778	. .	51 1	3 50	3 00	. .	6	331	27	677	. .	. .	58
52	Ware, Mass.	. . .	1¼ – 12	561	. .	11 5	. .	. .	. .	0	114	1	119	. .	. .	. . .
53	*Watertown, Mass.*	C. L., C. I.	2 – 16	1 707	. .	34 7	. .	0 17	. .	2	337	7	379	. .	. .	. . .
54	Wellesley, Mass.	C. I.	4 – 12	7 961	0	30 5	0 81	0 3	0 5	14	270	12	214	9	4	70
55	Whitman, Mass.	C. L., C. I.	1½ – 12	1 895	. .	17 0	. .	0 06	. .	3	151	3	89	. .	. .	65
56	*Wilmington, Del.*	. . .	. .	8 597	. .	102 2	. .	. .	. .	18	765	85	. .	. .	. .	
57	*Winchendon, Mass.*	C. I.	. .	. .	. .	15 2	. .	. .	. .	7	121	3	158	. .	. .	107
58	*Woburn, Mass.*	. . .	. .	. .	. .	. .	. .	. .	. .	9	352	10	422	. .	. .	. . .
59	Woonsocket, R. I.	C. I.	4 – 20	3 696	. .	45 8	3 57	0 46	0	8	548	8	456	. .	15	50–120
60	*Worcester, Mass.*	. . .	2 – 40	17 424	. .	173 5	. .	. .	. .	49	1 763	70	2 432	. .	. .	70 L S 150 H S
61	*Yonkers, N. Y.*	. . .	. .	19 800	. .	74 1	. .	2 71	. .	47	771	43	498	. .	. .	. . .

[1] Not including 10 483 feet taken by the Metropolitan Water Works. [2] Public hydrants only.

1900. — TABLE V. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — SERVICE PIPES.

Number.	Name of City or Town.	16 Service Pipe. Kind.	17 Service Pipe. Size. (Inches.)	18 Service Pipe. Extended. (Feet.)	19 Service Pipe. Discontinued. (Feet.)	20 Service Pipe. Total in Use. (Miles.)	21 Service Taps. Number Added.	22 Service Taps. Total in Use.	23 Average Length of Services.	24 Average Cost of Services.	25 Meters. Number Added.	26 Meters. Now in Use.	Percentage of Services Metered.	27 Motors and Elev'tors Added.	28 Motors and Elev'tors Total in Use.
1	*Albany, N. Y.*	...	...	...	...	...	...	...	...	...	66	2 030	.	.	.
2	*Andover, Mass.*	C. L., L. L., Tarred, L., C. I.	¾ – 4	2 008	...	12 1	31	876	73	...	.	643	73	.	.
3	*Arlington, Mass.*	...	...	...	...	...	76	1 570	...	...	5	71	2	.	.
4	Atlantic City, N. J.	C. I., L., G. I., T. L. G. I.	½ – 4	...	...	...	293	4 249	...	...	318	3 298	78	.	.
5	Attleboro, Mass.	...	...	...	...	...	...	...	...	...	105	957	.	.	2
6	Bay City, Mich.	Lead, W. I., C. I.	⅜ – 8	...	...	...	42	2 201	...	...	51	826	37	.	.
7	Billerica, Mass.	...	...	2 545	...	...	20	205	66	...	13	67	33	.	.
8	Boston, Mass.	C. I., Lead.	½ – 8	36 500	9 059	460	1 434	87 525	28	$15 28	0	4 516	5	16	665
9	Brockton, Mass.	W. I., L. L., C. L., C. I.	¾ – 8	8 263	252	31 5	135	5 275	60	...	164	4 300	81	.	.
10	Burlington, Vt.	G. I., C. I., Lead.	½ – 6	1 891	120	18	61	3 350	31	9 01	190	2 311	69	0	35
11	Cambridge, Mass.	...	...	...	...	...	158	14 207	...	...	270	860	6	.	.
12	Chelsea, Mass.	Lead.	⅝ – 2	1 779	0	31 3	62	6 146	28	15 00	12	104	2	1	7
13	Concord, N. H.	...	...	1 475	...	14 9	57	3 340	...	...	95	1 010	30	.	.
14	*Dover, N. H.*	Cement Lined.	...	1 300	...	16 7	20	1 813	49	...	.	463	26	.	.
15	*Erie, Pa.*	...	¾ – 6	7 149	537	43 7	378	1 154	...	...	.	270	2	.	.
16	Essex Junc., Vt.	Galv. Iron.	¾ – 2	6 000	...	1 1	120	96	50	12 00	36	36	37	0	0
17	Fall River, Mass.	Lead.	½ – 2	...	...	...	160	6 943	...	...	181	6 544	94	.	.
18	Fitchburg, Mass.	W. I., C. L., C. I.	¾ – 8	...	...	...	73	4 432	...	...	103	2 427	55	3	94
19	*Geneva, N. Y.*	...	...	...	...	...	158	1 679	...	...	319	966	61	.	.
20	*Haverhill, Mass.*	...	...	...	...	...	85	5 319	...	...	41	563	11	.	.
21	Holyoke, Mass.	C.L., Rubber Lined, Enameled, C.I.,L.L.,G.I.	⅝ – 4	1 266[1]	...	13 7[1]	76	3 610	20	16 46	5	210	6	1	96
22	*Hull, England*	...	...	...	...	...	...	...	...	...	.	789	.	.	.
23	*Ipswich, Mass.*	Lead, G. I.	¾ – 3	3 382	...	6 5	30	647	...	...	11	138	21	.	.
24	Keene, N. H.	W. I., C. L., G. I., Lead.	¾ – 6	840	0	9 8	28	1 725	...	...	9	103	6	0	10
25	*Leicester, Mass.*	...	...	...	...	...	14	305	...	...	.	...	.	.	.
26	*Leominster, Mass.*	Cement Lined.	...	6 813	...	...	96	...	...	...	.	394	.	.	.
27	*Lewiston, Me.*	...	...	3 165	...	...	31	...	...	...	.	64	.	.	.
28	Lowell, Mass.	W. I., Tin L., L. L., Lead.	...	4 666	...	7 9	115	10 634	...	...	326	5 586	51	.	.
29	Lynn, Mass.	C. L., L. L.	¾ – 4	2 652	489	105 4	191	13 504	...	...	235	2 571	19	.	.
30	Madison, Wis.	Lead.	...	...	...	14 0	...	2 758	...	...	.	2 586	94	.	.

31	*Manchester, N. H.*	. . .	½ – 6	2 627	. .	26 7	97	5 513	. .	. .	173	3 667	67	.	.
32	*Marlboro, Mass.* .	. . .	. .	. .	. .	. .	—45[2]	2 181	. .	. .	54	1 141	52	.	.
33	{ District suppl'd by Met'politan W. W. }	. . .	. .	. .	. .	. .	1 766	134 496	. .	. .	151	10 385	8	.	.
34	Middleboro, Mass. .	C. L., Lead.	¾ – 3	1 302	. .	9 3	29	820	45	. .	22	349	43	0	7
35	Minneapolis, Minn.	Lead, G. I.	⅝ – 1	. .	. .	. .	. . .	20 064	. .	. .	916	5 030	25	1	20
36	Nantucket, Mass. .	Lead, G. I.	½ – 2	326	74	2 2	32	929	13	$5 25	0	0	0	0	0
37	Nashua, N. H. . .	G. I.	¾ – 2	. .	. .	. .	. . .	. . .	. .	. .	24	475	.	.	8
38	New Bedford, Mass.	Lead, C. I.	½ – 10	6 558	416	61 4	129	9 280	35	28 33	331	1 429	15	17	116
39	New London, Conn.	W. I., C. L., G. I., Ld., C. I.	½ – 4	1 973	221	11 3	105	3 088	19	11 26	4	229	7	0	17
40	Newton, Mass. . .	Lead, W. I., C. I.	½ – 6	10 624	8 467	79 4	142	7 087	59	23 00	259	6 001	85	0	17
41	Oberlin, Ohio . . .	G. I., Lead.	¾ – 2	. .	. .	. .	29	625	25	8 00	87	392	63	0	0
42	Plymouth, Mass. .	Lead, C. L.	½ – 1	569	. .	6 0	61	1 894	16	5 62	.	. . .	.	0	1
43	Providence, R. I. .	Lead, C. I.	½ – 10	. .	. .	. .	598	21 566	. .	. .	689	17 843	83	7	161
44	Quincy, Mass. . .	G. I., Lead, L. L.	⅝ – 3	. .	. .	. .	441	4 330	30	14 00	10	122	3	.	.
45	Reading, Mass. . .	G. I., C. L., L. L., C. I.	¾ – 6	3 652	66	14 1	41	1 057	89	41 95	45	962	91	1	3
46	*Salem, Mass.* . .	. . .	. .	. .	. .	. .	59	. . .	. .	. .	.	185	.	.	4
48	Somerville, Mass. .	Lead, C. L., L. L.	½ – 1½	8 987	. .	65	238	10 291	33	. .	.	202	2	.	8
49	Springfield, Mass. .	Tarred, G. I., C. I.	½ – 6	. .	. .	. .	308	9 764	. .	. .	224	3 122	32	4	230
50	Taunton, Mass. . .	C. L., Tin L.	¾ – 3	5 860	. .	43 3	136	4 502	51	35 41[3]	99	1 832	41	0	16
51	Waltham, Mass. . .	C. L., W. I., C. I.	¾ – 10	4 334	890	38 6	58	3 285	53	23 46	0	78	2	0	6
52	Ware, Mass. . . .	. . .	. .	. .	. .	. .	11	727	. .	. .	17	735	100	.	.
53	*Watertown, Mass.* .	. . .	. .	. .	. .	. .	52	1 583	. .	. .	213	1 427	90	.	.
54	Wellesley, Mass. . .	C. I., C. L., W. I.	½ – 6	6 100	. .	15 7	42	878	94	13 15[3]	31	799	91	0	1
55	Whitman, Mass. . .	. . .	. .	. .	. .	. .	23	988	. .	. .	.	462	47	.	.
56	*Wilmington, Del.* .	. . .	. .	. .	. .	. .	338	. . .	. .	. .	120	688	.	.	.
57	*Winchendon, Mass.*	. . .	1	. .	. .	. .	58	388	19	. .	.	373	96	.	.
58	*Woburn, Mass.* . .	. . .	. .	. .	. .	. .	27	2 896	. .	. .	3	67	2	.	.
59	Woonsocket, R. I. .	C. I., Lead.	⅝ – 6	901	0	6 3	87	2 193	11	11 38	61	1 899	87	0	12
60	*Worcester, Mass.* .	. . .	. .	14 289	. .	121 2	284	13 292	48	. .	310	12 529	91	8	353
61	*Yonkers, N. Y.* . .	. . .	¼ – 8	. .	. .	. .	. . .	4 968	. .	. .	230	4 852	100	.	.

[1] Estimated. [2] Loss. [3] For current year.

EELS IN WATER WORKS AND THEIR CONTROL.

BY DR. GEORGE W. FIELD, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON.

[*An Informal Talk at the Meeting of March 13, 1901.*]

The eel is a good deal like the dog which some compassionate man noticed apparently stranded in a country railroad station, and he asked the baggage master why the dog was there, and where he was going. The baggage master said, " Stranger, I don't know where that dog is going, and he don't know nuther. He has et his tag."

The eel question is similar. It is extremely difficult to get any accurate information in regard to the habits of this animal. We all know and have known eels from boyhood; we all know something about them, and we all know something different. If you interview the fishermen about them you will get almost as many different answers as you ask fishermen. If you ask them if they ever saw a male eel, they will say No. If you ask them how eels breed, they will say they don't know; they must breed some way, but they don't know anything about it. That is the condition which obtains to-day, and that is the condition which obtained eighteen hundred or two thousand years ago. We find old Aristotle describing the eel as " an animal which is neither male nor female, but which generates spontaneously in the mud." You ask a fisherman how eels breed, and the chances are more than even that you will to-day get an answer similar to that. It is really only within three years that we have found out anything about the breeding habits of the eel. I would like very much to turn this into an experience meeting. I will tell you what little is known about eels, and will perhaps give you a hint or two as to what can be done to prevent trouble from them in the water works; and then I will ask you in turn to relate your experiences with eels in various water works, how many of you are troubled by them, to what extent, and so on.

Besides this statement that eels are generated from the mud spontaneously, there is a very current belief among boys, and among

some men, that eels are generated from horsehairs. Perhaps we all have had this idea at one time; I know I did. You have often seen these hairlike worms in the pools and mud puddles, and it is a common belief that those little worms turn into eels. Other people hold that eels are generated from old snake skins and eel skins. Further, it has been suggested that eels pair with the water snakes, and that the young are a cross between a water snake and an eel; but, of course, that is entirely out of the question. In Germany there is in the rivers an eel-like animal which gives birth to living young, and so the Germans refer to that as the mother eel, — *die Aalmutter*, — and regard this one animal as the source of all the eels. Of course this is a confusion of two entirely distinct animals. Then, further, many people say that eels come from other fishes. Of course this is a confusion with the internal parasites, of which all fishes have a great number. They have seen, perhaps, internal parasites in other fishes, and from their shape and perhaps color, have inferred that they are young eels.

It is probably unnecessary to say that there are many species of eels, but it is an interesting fact that where one species of eel is found in fresh water the same species is found in the salt water in that immediate region.

Now, that we may know what we are talking about, I will say that we are talking about the common eel of New England, which is not this one [referring to a specimen]. This is a specimen of the lamprey, which you probably all know, — the large, round-mouthed eel which runs up in the spring, and which is sometimes seen carrying stones to make a nest. This is a very small specimen, which I brought for convenience.

The study of the difference of appearance between the male and female eel is extremely interesting. If you examine a pile of eels in the market, the chances are you will find perhaps ninety-nine out of every one hundred are female eels. In general appearance, the male eel is very much smaller than the female. The full-grown male eel is scarcely ever more than fourteen inches long, whereas the female eel may be much longer, and frequently is as it gets to market. The snout of the male is very much more pointed than that of the female eel. The nose of the female eel is broad and blunt. The color of the male eel is described as deep, darkish green, or even deep black, with a silvery luster, and a whitish belly; while the female has a clearer color, usually of a greenish hue and black, and yellow-

ish on the belly. The male has apparently more pigment, is much blacker than the female, and the female is more yellowish on the belly. The dorsal fin is very much lower and less developed in the male than in the female. But the most marked difference is in the eye. The eye of the male eel is very much larger than the eye of the female eel, and that is apparently associated with the fact that the male eel lives in the deep sea, and never runs in the rivers. It is believed that the male eel spends its entire life in the deep sea, while it is the female eel which runs up the rivers in the spring, when it is perhaps two inches long, and lives in our reservoirs and ponds until the next spring, or later, when it becomes sexually mature, and then runs down to the sea to lay its eggs. It is a question whether it comes back or not. An examination of the female eel indicates that all the eggs mature at the same time, thus differing from many other animals. If you examine other animals you will find some eggs larger than others, tapering down to very small ones, which indicates that the eggs are laid either separately, or in small batches; while in the eel you find them all of the same size, which indicates that all the eggs which the animal is capable of producing during its life are laid at the same time. And, by comparison with other animals where the same condition obtains, the inference is that the animal dies as soon as all the eggs are laid.

It has been definitely settled that the eel lays its eggs like other fish, and does not give birth to living young; neither are eels generated in the mud, as is often believed. Of course you can readily see the basis of the idea in the fact that eels hide themselves in the mud and are found there in various sizes.

Now the development of the eel goes on, as I have said, in the ocean. The eggs are laid there, — they have been found to be about one-fortieth of an inch in diameter; and their development goes on at the expense of the yolk, just as in the case of the hen's egg. The yolk is constantly growing smaller, and the animal itself, which developes from the egg, is constantly growing larger, until, when the yolk disappears, the animal is able to live an independent life. So it is with the eel. I have some photographs here, kindly loaned for this occasion by Dr. C. H. Eigenmann, of the University of Indiana, who made some investigations last summer at the Woods Hole Laboratory of the United States Fish Commission. He succeeded in finding, out in the Gulf Stream off Nantucket, some eggs which he kept in an aquarium, where they developed into eels; and

he has made some photographs,* which I have here marked from one to eight, showing the different stages in the development of this particular eel. I want to say that this is not one of our common eels, but it is very closely related to it; it is certainly an eel, and the belief is that ordinary eels go through practically the same stages, so that for our purposes we may use what information we can get from this as representing the development of the common eel.

You will see [in the photographs] the food yolk on the anterior part of the eel, and notice that when we come down to the fourth stage it has disappeared; and in this condition the animal, swimming free in the surface water, is able to get its own food. Then you will notice in the next figure how the jaws are beginning to develop, and when you get to the eighth figure you will see a very marked development of the head and of the jaw.

Here are some later stages which show fairly well the appearance of the animal as seen under a microscope. You will be able to make out the eel-like characteristics. Then in this third drawing we have a still later stage, when the animal is about a week old. This shows the head magnified, and you will notice particularly the development of the teeth. It has in this young stage very remarkable protruding teeth, three or four on each side, showing that even in these young stages it is very fierce and voracious, destroying other fish. As it develops it loses these teeth, and acquires the small teeth with which you are familiar, perhaps in a practical way.

Until last summer, about all that we knew of the eel in a scientific way was due to Professor Grassi, of the University of Rome, who spent four years in studying the development of this one animal, and who obtained some very remarkable results. Up to Grassi's time there had been described an animal which was long and ribbon-like, represented in Fig. 1 on the accompanying plate, — transparent, with approximately one hundred and fifteen pieces in the backbone. Grassi succeeded in getting specimens of these at Messina, which is a remarkable place for marine life, from the fact that the strong currents throw up there the animals which live on the bottom of the deep sea. Perhaps you know that is the region which Homer described as Scylla and Charybdis, where so many vessels were wrecked. Now Professor Grassi found at that point a considerable number of these fish, which had, until then, been described as an independent

* These photographs could not be obtained for publication. — ED.

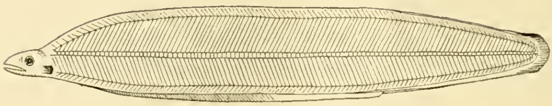

FIG.1.

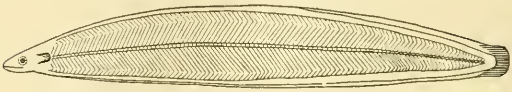

FIG.2.

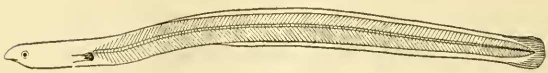

FIG.3.

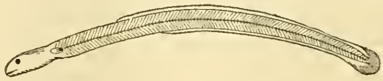

FIG.4.

FIG.1-LEPTOCEPHALUS BREVIROSTRIS.
FIG.2-LEPTOCEPHALUS BREVIROSTRIS.-LATER STAGE.
FIG.3. ANGUILLA VULGARIS. TRANSITION STAGE.
FIG.4. ANGUILLA VULGARIS DEFINITIVE HABIT. (ELVER).
AFTER GRASSI

[FULL SIZE.]

species. No one then suspected that they were young eels, and they had been given a different name, — *Leptocephalus brevirostris*, — which means, literally translated, the short-nosed thin head. You see he has a small, short head and a long, thin, ribbon-like body.

Professor Grassi kept these in aquaria, and found that instead of increasing in size they took no food and diminished in size, passing through a most remarkable change. In fact, the young eel, which develops from this larva, is as much unlike the ordinary eel as a caterpillar is unlike a butterfly. The change, or metamorphosis, which it undergoes is very much like that undergone by the caterpillar in changing into the butterfly. He found these fish, represented in Fig. 1, at the surface, and also in the stomach of a deep-sea fish, — *Orthagoriscus mola*. Hence it was learned that these animals must live on the bottom of the sea; and when Professor Grassi put them in his aquaria, he found that they burrowed into the mud at the bottom, showing that they live at that time of their lives almost exactly the same as the mature eels. In about a week they had the appearance shown in Fig. 2, a little smaller, though not so very much changed. In the third stage, say perhaps two weeks later, he found that the head was developing, becoming rounder and somewhat shorter. But the shortening was most evident at about a month after hatching, when the conditions were about those shown in Fig. 4.

I have here in bottles some actual specimens of young eels, which were taken at the surface at Pensacola. These were very kindly loaned for the occasion by Professor Garman, of the Agassiz Museum of Zoölogy at Cambridge. I will ask you to look very carefully at these and notice particularly the eel-like head, the length of the body, and the thinness. If they were alive they would be transparent, but now they are coagulated by the alcohol. I will ask you to note particularly the change in the size of the eyes. I said the male eel had larger eyes than the female for the reason that they live in the deep sea; so these larvæ, which live in the deep sea, have larger eyes than the ordinary eels. And you see as the eel develops and comes towards the shore, preparatory to ascending a stream, the eyes diminish in size; that is well shown on the diagram and in the specimens.

Now the eel is, as you know, largely a nocturnal animal, and on dark, stormy nights in March, April, and May, these eels ascend the rivers in vast numbers, when they are between two and three inches

long. You may then see them accumulating just below a waterfall, searching for some way among the stones to work their way up above the obstacle. During all this time they are very ravenous, but they are kept in check very largely by the pickerel, the trout, the bass, and by other carnivorous fishes in the rivers, and, of course, only a small percentage of them get into the ponds. So far as we know, these are all female eels that are running up. Once in the ponds they grow very rapidly, spending most of their time, particularly at night, nosing around among the stones, and in the young stages living on the crustacea, worms, and other animals which live under the stones; then, as they get larger, lying in ambush and darting out for the fishes, until at length, as full-grown eels, they can dispose of very good-sized trout or bass; and, undoubtedly, they kill a great number of valuable food fishes. Of course, in the ponds and reservoirs, they are valuable to a certain extent as scavengers, by destroying a considerable quantity of decaying animal matter.

If, for any reason, these eels are shut off from the ocean and cannot return, they remain in the ponds, increasing in size but never reaching sexual maturity. They would migrate if they could, but if they can't they continue to grow, but apparently never develop eggs. And here is a practical point. If a pond is shut off from the supply of young eels, there is no increase in numbers. The eels which are there increase in size, but after a time, of course, they die from natural causes.

Now let us look for a moment at some of the reasons why there has been so great a lack of knowledge in the life history of this animal. First of all is the remarkable fact that the female descends the streams to lay its eggs, differing in that respect from the fishes with which we are familiar, which run upstream to lay their eggs. Further, the spawning of the eel takes place not in shallow water, not in the ponds and streams where we can readily find the eggs, but in the deep sea; and the eggs that have been found, about a fortieth of an inch in diameter, were floating at the surface one hundred to one hundred and fifty miles from land. And again, the young which come from the eggs are entirely different from the adult, and these larvæ are rarely found at the surface, and in the stomachs of deep-sea fish.

We have, perhaps, gone sufficiently into the life history of the animal. I will only refer to one more point, and that is that the eel puts on a bridal dress. In the spring, when they are migrating to the

sea, they change color. The yellow is replaced by a beautiful silvery-white. The probability is that the eels which are known to fishermen as "silver eels" are the adult or sexually mature females on their way to the sea. In addition to this silvery coloring, there is a great increase in the black color, particularly of the fins. But most remarkable is the fact that their eyes enlarge.

Now just a word in regard to the application of this knowledge of the life history of the eel to practical purposes. During the naturalists' meeting at Baltimore, an engineer of the water works asked me what he could do to take care of the eels. He said they were a great nuisance. They had to stop the machinery about once a week and would take out a barrel or more of eels in various stages of maceration, which had been caught in the machinery; and, in addition, they had to keep men ready to answer emergency calls. I looked at the map of the water supply and inspected the dam, and I saw that there was no obstacle to prevent these eels, two or three inches long, going up in enormous quantities and getting into the pond, and there developing into mature eels. Then at the time when they would go down stream naturally the wasteways are usually closed, and the only way that the eels can respond to this migrating instinct is to go into whatever is open, and in this case, you see, it was the large service main.

Now the suggestion which I have to make is a very simple one, and it has probably already suggested itself to you; that is, that an eel-tight overhang should be made at the wasteway of sufficient height so that they cannot work their way under and cannot get over. Then, if a way to get out is supplied, and there is no way for more eels to get in, it is only a question of a short time when the eel nuisance will be abated, if not entirely done away with. There is no reason, theoretically, why it should not be entirely done away with, if you have an eel-tight overhang at the wasteway. It need not necessarily be very high, for the majority of the eels which go in are only two or three inches long.

Now I should like very much to know something about the experience of you practical men in this line, — how many are troubled with eels. I would be very glad, if any one has any special questions to ask, to attempt to answer them. We don't know very much, after all, about eels, but I should be glad to answer any questions that I can.

DISCUSSION.

Mr. D. H. Gilderson.* I would like to ask Dr. Field how much of an overhang he would suggest. We have had a good deal of trouble in our town. We have one pond that is one hundred and ten feet above the river, and there is only one month in the year that there is any overflow from it. We pumped our reservoir full a year ago last fall, and we did n't happen to use it that year, and when we drew the reservoir down in the spring we found over one hundred eels, ranging from three to nine inches in length.

Dr. Field. At what time of the year did you draw it down?

Mr. Gilderson. We drew it down in the last of April. I wanted to know how large an overhang you would suggest. It is only from two weeks to four weeks in the year that there is any water running out of this pond.

Dr. Field. What time of the year is that usually?

Mr. Gilderson. Last year it was along about the first of March, but this year the water is n't up within five feet of running over; it varies in different years.

Dr. Field. The bulk of this migration takes place here in April and May. In many cases, of course, it is unnecessary to have an overhang, or take any of these precautions, for the reason that the dams on the streams below are effective; and, if there are any water works in this section which are not troubled with eels, the chances are that there are some dams below on the stream which stop the migration of the eels, or it may be that there are other ponds in which the eels can find everything they want, and so they stop there. I think that is probably the case in Brockton, where the eels follow up from the Taunton River and stop in the large ponds below, and do not get up into the reservoirs. Ordinarily, I should say that an overhang of two or three feet would be sufficient to answer all purposes. That would depend, of course, on how difficult it was to make it, but if it is tight at the bottom I don't believe an eel two or three inches long could go much over a foot, or possibly two feet at the most. It seems to me three feet would be amply sufficient. Does that cover your point?

Mr. Gilderson. Yes, sir. I would state, if it will be of any interest to you, that it was Kenoza Lake, at Haverhill, which I have spoken of.

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*Superintendent, Haverhill, Mass., Water Works.

Dr. Field. I am glad to know of the case, and I would like very much to hear of other places where there has been trouble.

Mr. George F. Chace.* I should like to ask Dr. Field a question. I understood him to say that the eels always spawn in deep water of the sea, and not in the ponds?

Dr. Field. Yes.

Mr. Chace. I should like to know how long it takes one of these young eels to grow to be a foot and a half in length. The reason I ask is because there have been a great many large eels in Elder's Pond in Lakeville, and that pond has had no connection with the sea for at least eight or ten years.

Dr. Field. There is a parallel case, which is a very interesting one to zoölogists, and that is the old sewers at Rome. You know there is an extensive system of old sewers there, and in them has developed apparently a particular variety of eel. It grows to a certain size and gets no larger; and, being in a sewer where it is dark, it has developed large eyes like the deep-sea fishes. It does not become sexually mature, although it apparently lives for an almost indefinite time. It is generally known, of course, that fishes are relatively long-lived animals. The eels probably enter during floods and may remain for years.

Now with regard to the case at Lakeville, it is apparently somewhat similar to that of the Roman sewers. The eels there probably ave developed, and they may never get any larger, though ordinarily, if there is an abundance of food, as I should think there would be there, they continue to grow until they die from natural causes. Apparently the conditions differ somewhat, but the ordinary rule is that they grow very large and gradually diminish in numbers. The eggs of an eel which spawns this spring, we will say, in the ocean, develop before the next spring into eels two or three inches long, and it is probably that stock which goes up the stream in great numbers. If the eggs are laid this spring, the young will go up next spring. Now the rate at which the eels will grow in any particular pond depends entirely upon the food supply. I have no practical knowledge as to just the rate at which they grow, and I know of no experiments or observations which have been made on their rate of growth, but the probability is that with plenty of food they will grow very rapidly up to a certain size, then growth gradually becom-

* Superintendent, Taunton Water Works.

ing less rapid, and then they may remain at about the same size for an almost indefinite time.

Mr. John C. Chase.* The only thing I have to offer on the eel question is of a historic nature, and treats the subject from the standpoint of a food rather than as an annoying incident of a public water supply.

The Merrimac River was a famous abiding place for the lamprey eel in the early years of the century. They went up the stream in the spring in great numbers, and the inhabitants for miles around the Amoskeag Falls in Derryfield, now Manchester, resorted there to catch and salt them for future consumption, and they went by the name of "Derryfield beef."

The poet of the centennial celebration of the incorporation of the town, held a half century ago, alludes to them as follows: —

"For I cannot give e'en a short address
On my fathers' home, their woes, their weal,
And omit the claims of the squirming *eel*.

"'Ignoble theme!' does the critic say? —
But what care I for his sneering bray?
In my boyhood's days upon eels I fed,
And as now to you, I a banquet spread
Of such simple food as the past reveals,
I invite you now to a dish of eels.

* * * * * * *

"Our fathers treasured the slimy prize;
They loved the eel as their very eyes;
And of one 't is said, with a slander rife,
For a string of eels he sold his wife!

"From the eels they formed their food in chief,
And eels were called the 'Derryfield beef'!
And the marks of eels were so plain to trace,
That the children looked like eels in the face;
And before they walked — it is well confirmed,
That the children never crept but *squirmed*.

"Such a mighty power did the squirmers wield
O'er the goodly men of old Derryfield,
It was often said that their only care,
And their only wish, and their only prayer,
For the present world and the world to come,
Was *a string of eels and a jug of rum!*"

The building of dams for the development of the water power of the river has put an end to the running up of the eels, and I under-

* Civil Engineer, Derry, N. H.

stand that at the present time neither eels nor rum are on the bills of fare at Manchester.

MR. J. C. HAMMOND, Jr.* Some thirty years ago we had a great deal of trouble with eels in our reservoir, and the turbine wheels in the mills would fill so as to stop the mills. I remember once we took one out of a three-inch pipe in the street which entirely filled the pipe, and completely shut off the water. Of late years we have had no trouble with them, and I think that now, after listening to Dr. Field, I understand the explanation of it. In the Sixties we rebuilt our dam, and the water was very low, so the gate was not closed at all, and there was ample opportunity for eels or anything else to go from the lower pond into the main pond, and there are few if any there now. There are no eels caught in the pond, and we don't see any there, so they must have gone out, when they had a chance to, a great many years ago.

We used to leave our gate open about an inch and a half at night, so as to keep the ponds below full in case of fire. The man in charge of the gate went up there one morning and found the pond next below the dam entirely dry. He was very sure he had left the gate as usual, and upon raising it the water started, and when he looked down into the pond below he saw an enormous eel there. He *said* it was three or four feet long. He did n't catch it, and that is perhaps the reason he said it was so large; but, at any rate, it was big enough to have filled the inch-and-a-half opening in the gate, and shut the water entirely off. I presume that it was one of the old settlers.

MR. HARRY L. THOMAS.† There is something in this question that interests me very much. We have had more or less trouble with eels, and, although we have sometimes thought we had gotten rid of them, they would came again. I have always taken it for granted that the eels went into the main when they were very small — of course they must be small in order to get through the screens, which have, perhaps, a quarter or three sixteenths inch mesh. So far as I know, it is quite impossible for any of the young eels to come up and get into our pond, and I have wondered, if that is the case, whether they would not in time entirely disappear from the system. I would like to ask if it is possible for eels to die in the mains from any cause? I presume others have had the same complaint, but once in a while, when a consumer thinks he is getting poor water, he comes to the office and says it

* Treasurer, Aqueduct Company, Rockville, Conn.
† Assistant Superintendent, Hingham Water Works.

tastes as though there were dead eels in the pipe. We have never been sufficiently familiar with the subject to be able to say whether there were dead eels there or not, and I have often wondered whether it is possible that they died a natural death there.

Dr. Field. I think it is very probable they die a natural death, or very likely from starvation, after getting lodged in a small pipe. In regard to the other point, it seems to me probable that you will, in a very short time, get rid of eels if you are absolutely certain that there is no way for the small ones to get into the pond. I think that while it is possible that they may increase in size somewhat in the mains, the chances are they would n't grow a great deal. Can you tell how large the eels have been that you have found in the main?

Mr. Thomas. They bother us the most in certain localities. Apparently as they are going by a corporation the suction through the service will sometimes knuckle them into it. Our method of procedure then is to put a force pump on the service faucet, open the hydrant beyond, and force them out. We are generally successful in doing that, and we have taken out some, that is, that are from twelve to sixteen inches long. We have blown them out of the hydrant, and they would be alive when they came out.

Dr. Field. I should hardly call an eel of that size a large eel, as I would use the term, and I think it very probable they may have grown to that size in the pipe. It would depend entirely on how much food they got. Most of these animals, as I say, grow according to the amount of food they get. With abundance of food they grow rapidly; with a little food they grow very slowly, and I can't tell how long it would take them to grow to the size you mention. Do you know anything about the conditions, how long they had probably been there, or how long since it has been impossible for any eels to get into the pond?

Mr. Thomas. That I cannot say.

Dr. Field. Points like that would be extremely valuable to know about in solving this question, and, if you can find any data, I would be more than obliged to you if you would give me the information.

Mr. Thomas. I may say that it occurs to me now that the calls to blow eels out of the services and to clean out our eel-traps seem to have been less frequent of late. In the two or three particular localities where we put in eel-traps to catch the eels alive, we used to visit them quite frequently, and find them almost full at times;

now we go there less frequently, and we have fewer calls to blow out eels from the service.

Dr. Field. How long have your water works been in operation?

Mr. Thomas. Twenty-one years.

Dr. Field. Have there been any special changes made in the wasteway lately?

Mr. Thomas. The pipes from our gatehouse are just the same as always.

Dr. Field. There may have been certain conditions which have brought about the difference in the number of eels at various times. If, for example, during March, April, and May the water was running to waste in any particular year, there would be a chance in that year for the eels to run in; and, if the next year the water was not running out at that time, eels could not get in; and so it might happen that on that account the number of eels noticed in one year would be greater than in other years.

Mr. Charles W. Sherman.* I should like to ask Dr. Field whether the polyzoa and similar organisms, which form a quite noticeable slimy coating on the interior of the pipes in many supplies, would be a suitable food material for eels?

Dr. Field. I should say not. Eels are purely carnivorous, so far as I know. Perhaps the main source of food for the larger eels, if there are a great number of eels in the pipes, would be smaller eels and small fish.

Mr. Leonard Metcalf.† I should like to ask Dr. Field in regard to the period of time within which eels, in the natural course of events, in an open stream, would return to the sea. He said that the eggs which were laid one year would develop so that the small eels would perhaps go up next spring. Now in an unobstructed stream, upon which there were no dams, and along which there were ponds in which the eels could get liberal food supply, when would you expect them to return to the sea?

Dr. Field. That would depend on the amount of food they had.

Mr. Metcalf. Suppose they had ample food in a pond, would they return the next year?

Dr. Field. The probability is they would return the next year.

Mr. Metcalf. As I understand it, they would return to the sea, lay their eggs there and die.

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*Civil Engineer, Metropolitan Water Works, Boston, Mass.

†Civil Engineer, Boston, Mass.

Dr. Field. It is supposed so, arguing from analogy. Similar animals which deposit all their eggs at one time then die; and further, no sexually mature eels have been reported as running up in any large numbers. There is a migration in the fall, in certain regions at least, of the eels which come from salt water and run into the brackish ponds, so common along our shores, and locate themselves in the mud and remain there hibernating. You probably have seen the fishermen spearing them through the ice, prodding their spears down into the mud. Have I covered your point sufficiently?

Mr. Metcalf. Yes, sir.

Mr. Richard A. Hale.* At Lawrence there is quite an extensive migration of lamprey eels every season, coming up the fishway, along in May and June. Along the later part of June the ordinary silver eel is noticed, four or five inches long. I think the quantity has been slightly decreasing from year to year. There has been more or less trouble at the mills on account of the eels interfering with the wheels, but of late years there has n't been so much difficulty, because the iron racks have been arranged a little closer together and no openings have been left through which the eels could crowd. There have been cases where the eels have got in and filled up the wheel so completely that it has been necessary to stop the mill in order to clean them out. Later in the season I have often noticed many small ordinary silver eels, two or three inches in length, about the wheel pits and the dam, or wherever there is any moisture, and they will climb up perhaps five or six feet above the water. I don't know as there is any limit to their climbing; they seem to climb as long as there is any moisture.

Dr. Field. An overhang is practically the only thing which will stop them.

Mr. Hale. The overhang at the crest of the dam would prevent them going up over the flashboards. On the retaining walls along the river it is very noticeable that where there is any moisture they gather and climb up. I suppose these are the ordinary silver eels, which grow to a larger size and possibly go up the fishway later. Along in the fall there is quite an extended migration down the river, and the Frenchmen catch them and salt them for the winter.

Dr. Field. Are these the common eels or the lamprey?

Mr. Hale. Almost entirely the common eels. I think Professor

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* Civil Engineer, The Essex Company, Lawrence, Mass.

Sedgwick has obtained a supply of lamprey eels from Lawrence, and perhaps he can say something about them.

Dr. Field. It is a well-known place for them, and a great many of our students get their supply for dissection from Lawrence, through the kindness of the officials there.

A Member. I remember some seventeen or eighteen years ago, at the time my father had charge of the works I am connected with now, he set a line out at the station one evening; and the next morning, when the engineer and I arrived, we found him in the pumping station, covered with slime from head to foot, but he had an eel which was probably over three feet long, and I should say it was as big round as my arm. Father had its head screwed in the vise and was getting the hook out of its mouth.

I have noticed, when we did have eels in our works some time ago, we always got them at points where there was the lowest pressure. We could go to a certain point and open a hydrant and draw practically all eels out of the main, getting a bushel out of one hydrant, sometimes.

A Member. Will eels burrow into the ground any distance below the water line?

Dr. Field. Probably not into anything which is very firm. They ordinarily burrow in the mud, and they will overturn a good sized stone by burrowing under it. They are exceedingly strong. I doubt, very much, if they would burrow into a firm bank so far as to do any damage at all.

Mr. George W. Travis.* I once saw an eel caught in Lake Cochituate which weighed seven pounds; I don't know the length. I saw another caught through the ice in front of my pumping station this winter, about three weeks ago, which weighed five pounds. I think we have never had any trouble with the eels in our pipes.

* Superintendent, Natick Water Works.

THE APPORTIONMENT OF CHARGES FOR PRIVATE FIRE PROTECTION, AND THE MEANS OF CONTROLLING THE SUPPLY FOR SUCH SERVICE.

[*Topical Discussion at the Meetings of February 13 and March 3, 1901; the regulations of various cities; and preliminary report of a Committee appointed to consider this subject, presented September 18, 1901.*]

President Crandall called upon Mr. J. C. Hammond, Jr., of Rockville, Conn., to open the discussion.

MR. HAMMOND. Mr. President, I did not come here expecting to open the discussion upon this subject, or prepared to say anything which might be of value to others, but rather hoping that I might learn something of benefit to myself. However, as you have called upon me, I will say that we have in our place a private water company which furnishes water for the mills and also for domestic purposes. We make a charge for supplying water for fire purposes, for sprinklers, and, unfortunately, each one of the mills we supply has a different idea of what the others ought to pay and what he ought to pay; and I, not being a stockholder or director, am a sort of a fender, as it were, between the dock and the steamboat, and I thought I would come here to-day to see if I could n't get another layer of cork on me — in other words, some information. There are three ways of making a charge that I have thought of. One way would be, so much per square foot of floor space; another, so much apiece for sprinkler-heads; and a third method, a percentage on the amount of insurance carried. The objection to the first plan is that some of these mills have a large amount of floor space which is at times used for storage and at other times is unoccupied, while in other mills the floor space is filled with valuable machinery, so that a charge based on floor surface would not be just. The objection to the second plan appears when you want to protect the out-buildings (which may be filled with stock at times) with sprinklers, for there is no great value there even then as compared with a mill which is full of valuable machinery. By following the third plan, that is, charging a certain per cent. on the amount of insurance carried, a man would then pay for the protection he asked for.

I have been writing letters to different water companies, and I find nobody who seems to have had any experience. Apparently the water companies don't want to own up. One of our cotton mills was paying an extravagant rate for insurance, two or three per cent., and the factory insurance people came along and said, "Now, if you will put in sprinkler apparatus we will reduce your rate," and they have got it now down to one per cent., I think; and I know of one company which paid back 90 per cent. in dividends, so that the cost of insurance in such case is only one tenth of one per cent.

Now, if the mills get that benefit in insurance, they get it because we furnish the water. But some of them say, "We don't use the water: it is simply there." Well, my neighbor puts in a telephone, and he says, "Some day if I use it I will pay the same as I would pay at the office." But who is going to pay for it the other three hundred and sixty-four days? It is the same way with our water. They have hydrants in the yard, they have the benefit of sprinkler protection, and why should n't they pay us for it? Our city government pays us twenty dollars a year for a hydrant. We have practically the third system of water works which has been put in since 1846. The first one, which was put in mainly by the mills, never paid a dividend; in 1866 we had four or five hundred dollars in the savings bank and a lot of old rotten cement pipe, and we put in a new system then. The present system was installed in 1893–94. Now, suppose we laid our present twenty-inch main down through the city, and had but a few customers, — as would be the case in any town when it first establishes water works, — and connected up all these mills with sprinklers, and they said, "We don't use the water and we won't pay anything." How would we come out in fifty years when we had to put in another main? Each mill pays one hundred dollars now, and there is no more equity in it than for some of you gentlemen to pay one dollar and a half for your dinner and I pay seventy-five cents for mine, if you and I receive the same fare.

I want to be advised. Some of you say, "We don't make any charge"; but ours is a private corporation. Many cities which have their own water works have a system of keeping a separate account with the water works, and the city pays for hydrants. Now, why should n't the mills pay for water for sprinklers, even if they don't use them except in case of fire?

Mr. Charles K. Walker.* I am glad Mr. Hammond has brought

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*Superintendent, Manchester, N. H., Water Works.

this matter up, because I have had some experience myself. The mills have this fire service put in so they can protect themselves, but they don't pay anything for it, and they are awfully apt to tap it. There is nothing fair about that. One of these insurance fellows came around my way the other day, and they were going to put in a pump, so as to be sure, he said. Well, we had our pipes in the mill, and they had something they were not paying for, but they said, "Now, we want to put in a pump and pump out of the river, and we are going to have a signal to display when your pressure is on, and when the flag is down we are pumping." I said, "No, we are not going to do any more of this business. We are going to have a meter, and you must pay for what water you use, whether it is in the pipes you have got around the mill or in the pump. We don't propose to pump water for you to put through your pipes when your pump don't work. We want to know how much water you use." They said they did n't use any, but still they agreed to put on a meter. Whether they will actually do it or not I don't know, but I told them they must n't touch the water if they don't. They ought to pay something for water when they are stealing it. There is no way to do but to put on a meter where the pipe goes into the mill, and if they use the water in any way, shape, or manner, they ought to pay for it.

I think they ought to pay for the protection, but they don't; the city says, "You can have the water, if you don't use it, so as to protect yourself against fire." The insurance folks want it, and they don't care how much you do for them. I find corporations are about the same as individuals; they want to get this thing as cheap as they can, and I think the insurance folks do, too. You are on the right track, Mr. Hammond, and I think you ought to make them pay. I could talk a long time on this subject, but I can't stop any longer now. I hope this question will be discussed and ventilated right here, because we all want to know what to do.

Mr. E. V. French.* I am very glad, Mr. President, that Professor Niles has told us this afternoon of the great benefit of difference of opinion, for I am afraid I shall differ very much in what I shall say from Mr. Walker and Mr. Hammond; and, if we had n't been told how beneficial differences are, we might possibly be troubled about it.

Representing the underwriting side of this question, I appreciate

* Inspector, Associated Factory Mutual Insurance Companies.

very much what Mr. Walker has said, and it has seemed to me that when we come to discuss the matter there was no better way of doing it than to assume some case which would be a fairly typical one.

Now, suppose we take a certain town and. we will say, there are two manufacturing plants in the town, valued at about five hundred thousand dollars each. Mr. Hammond could easily find two such in Rockville. The manager of one of these plants thinks it desirable to depend entirely on city protection against fire, the city steamers and the public water department, and he does so. The manager of the other plant equips his establishment with automatic sprinklers, puts in a pump, and all those other things which Mr. Walker has told us the insurance inspectors delight to look over, and he wants water and asks the town for an eight-inch connection. Generally he is not at all modest, and he may ask for a ten-inch, and perhaps it is given to him. There is some discussion, very likely, at the time, as to how he ought to pay for it, but possibly he pays nothing.

Well, time goes on, and by and by a fire starts in the first plant. It happens to start, we will say, as fires so often do, in the interior, in the worst part of the establishment. Perchance it is a windy night. The alarm is given immediately; the town steamers — perhaps there are two of them — come down, the town fire department rallies, and a very hard fight is put up, but the fire lasts from midnight until well into the next day. The town steamers are worked for all they are worth, and very likely some repairs are found necessary for at least one of them after the fire; a good deal of hose is ruined, and one or two ladders are burned. The next day the fire is talked over, and everybody is very glad that it was stopped as well as it was. It may be that two thirds of the plant has been wiped out, but something has been saved, and the fire was prevented from spreading. Every one is glad, and no one doubts for an instant that it was the *duty* of the public fire department to pump thousands and thousands of gallons of water an hour on to the fire, and keep it up for ten or twelve hours.

The partial destruction of the plant very likely is a serious blow to the town. It is not at all impossible that changed conditions of manufacture make it desirable for the concern to build elsewhere when the question comes up of starting all over again. If they don't do that, which of course is the worst case we could suppose, quite likely it is several months before the plant is put into shape again, and three or four hundred, perhaps more, operatives are out of work for that

time. Quite likely many of them feel that they cannot wait these three or four months in idleness, and they go off to some other place. In all this the town is a direct loser, first from the wear and tear of fire apparatus; and second, and to a much larger extent, from the loss or temporary stopping of business of importance to the prosperity of the town. Still, probably no one suggests that the man ought to have put in any protection of his own. It is the *duty* of the town to put out fires; a man pays his taxes for this very thing, people say; and very likely the outcome of the whole thing is that another steamer is considered necessary, and the town buys it and spends a considerable sum of money each year in maintaining it.

Now take the other case. Suppose a fire occurs in the other plant, which is sprinklered throughout, has a good connection with the town water and a good pump. The experience of every underwriting organization in the country goes to show that the chance of a bad fire in such a protected plant is very, very much less than in the first plant. Probably a fire of the kind starting in the first case supposed in this illustration simply results in ten or fifteen sprinklers opening, and the mill fire pump running for a little while; very likely the public alarm is given, the firemen jump out of their beds, and when they get down to the mill find that the mill apparatus has been working, a few thousand gallons of water have been used, and the fire has been extinguished without any appreciable wear and tear of the fire department apparatus; and the next morning everything is running in the mill as usual. No one thinks much of anything about it; it is taken as matter of course, just as things were in the first case.

Now, is n't it fair to ask whether in this case it was not good business policy for that town to allow the manager, who wanted to protect his plant, a liberal and free connection so he could have water for the sprinklers? We all know that there is nothing better for a sprinkler supply than a good public water system, with its constant care, its necessity of being kept in service every minute, and generally its much larger capacity and higher pressure than would be available from any private tank. So, looking at it from that standpoint, we see that a man who spends very likely $15 000 for his sprinkler and pump equipment — and that would not be an excessive figure for a $500 000 plant — is really asking of the town a great deal less than a man who gets the fire department down there some night to try to put out a fire in his plant, and finally loses the plant.

It would seem, therefore, as if simple, ordinary, everyday business policy would indicate that it was the best thing for a town to grant to mills with protection a liberal water supply for fire purposes, and grant it without any annual charge whatever.

The minute you charge a man so much a sprinkler and so much a hydrant, just that minute there is a tendency for him to use one hydrant where he ought to have three and to want one sprinkler where he needs several. The whole effect of such a ruling by the water department is to scale down fire protection, which it is in every way, it seems to me, for the interest of the town itself that the man should put in; and he puts it in at his own cost, too.

Just one word on the question of quietly taking water for manufacturing purposes from fire pipes and paying nothing for it. We believe that the best arrangement is to have the fire pipes absolutely and entirely separate from the supply used for domestic purposes. We advise it and always lay out systems in this way. The idea is that the fire system shall have no draft of water through it normally, shall simply stand with open gates, ready to pour a deluge of water upon a fire the minute a sprinkler opens, or the instant a lone watchman at night takes a line of hose from a standpipe or hydrant, and be able to extinguish a fire before the pumps can be started. We do recommend that another connection, of any size needed, and generally much smaller than the fire connection, be taken in and metered, if desired, — generally it would be desired, — and that from that second connection *all* the water used for boilers, closets, and all purposes except fire be drawn. Then we always urge that the fire service connection be left unmetered. We all know that meters somewhat obstruct the service, and some of them may under possible conditions of clogging obstruct it very seriously; and we have therefore felt that it was very desirable to have the freest possible connection for the fire system, so as to get a good supply of water and get it right off. Waiting to open any valves in meter by-passes or anything of that kind is absolutely out of the question when you are talking about *automatic* sprinkler protection.

Now, going a little further, and taking up the question of private water companies, it is a little harder to deal with them in this way. The company naturally wants income; that is what it is in business for. But I think if we agree in the idea that it is good policy for any town to keep its manufacturing industries in the town and prevent them from burning up, by aiding them from the public

water supply, then I think we shall be irresistibly led to the conclusion that it is equally the duty of a town supplied with water by a private water company to compensate that private company, if necessary, out of the fire department funds of the town, for any cost which they found they had to bear on account of a connection into a private sprinkler system. This may seem a little radical, and we appreciate that it would be difficult to bring about in many cases, but it seems to me to be the only logical conclusion. It simply means this, going back to our assumed case, that if the unprotected manufacturing plant, being an important industry in the town, had asked the town to put three or four hydrants on adjacent streets, and pay a private water company, assuming there was one, thirty or forty dollars a year for each of them, the town would undoubtedly have granted that request, and would have paid the water company for those hydrants, and nobody would have thought anything about it; or if they did they would have said, "Of course we want to protect that plant." Now, if that man himself puts in apparatus, and simply asks for a connection through which a lesser amount of water will do immensely more good, the proper thing to do is, if there is any charge, to make it to the fire department of the town, which is in duty bound to protect that risk, and which department really should be glad of such assistance as private apparatus gives.

There is another point to think of, perhaps, in this connection. Sprinklers and other protective equipment, such as private pumps and hydrants in a large establishment, are not only useful in preventing that establishment from burning, but they are extremely useful in preventing conflagrations. They do this first by making it generally impossible for a small fire to become a large one; and, secondly, they do it by making it very unlikely that a protected plant will burn rapidly. Sprinklers in a protected building, even if that building is threatened by a severe fire in an adjoining building, will generally hold the fire; they very frequently will keep it from getting in, and when they do not do that they will generally make the sprinklered building so slow burning as to give ample time for the fire department to rally. I happened to be in Boston a few years ago, when the Ames and Brown-Durrell buildings were burning, on Summer and Kingston streets. I wanted to see what was going on, and so got on top of the building opposite the Brown-Durrell building on Kingston Street. It was a rapid fire, you will remember, and some of the people in the buildings did n't get out. Finally the flames beat

against the Brown-Durrell building, which was right across Kingston Street from the building I was on. Everybody noticed that the Brown-Durrell building burned slowly. People did n't know at the time why it was, but after the fire it was learned that the building was sprinklered. The fire which entered the Brown-Durrell building was fed outside by such an enormous mass of material that the sprinklers inside could not cope with it entirely, but they checked it, and there were about five minutes when it was a question whether the fire would get across Kingston Street or not. The glass in the windows of the building on which I was had begun to crack with the heat, and there were not sufficient hose streams in the street; but during that five minutes, when the sprinklers were retarding the fire, the firemen were rallying, the out-of-town apparatus and reserve apparatus were arriving, and at the end of that time five or six hose streams were brought to bear against the building and carried the day, stopping the fire at that point. If that building had n't been sprinklered, and if that critical moment in the fire had occurred fifteen minutes earlier, the fire would have gone across Kingston Street without the slightest doubt, and would have gone on. That is a case where the expenditure by the Brown-Durrell people of several thousand dollars for sprinkler protection, fed by a free city connection, and encouraged by the knowledge that if they put in that protection they would not be called upon to bear any further expense, undoubtedly saved the city a great deal of money. So, in a crowded district, or where there is a conflagration hazard, it would seem as if sprinklers were a good business investment, and a *free* supply of water to them the very best thing for a city or town to grant.

Again, if we go to a place where the water department keeps separate records, and is an absolutely independent department, the same thing applies that applies in a private company. It seems that if any annual charge is made by the water department for a connection with the city mains, that charge properly should be borne by the fire department; and I think it is the case in some cities that the fire department pays the water department so much a hydrant. I think the point is clear, that this matter of supply for fire purposes is a fire matter, not a water matter; and if any charges have to be made, it seems to me they should come out of the money which towns and cities freely and willingly appropriate to prevent the loss of property by fire.

I have put together a few figures which I think will be of interest,

simply to show the importance of sprinklers. In the Factory Mutual Companies there was last year an average of about $900 000 000 worth of property at risk, and there were about 450 fires, giving a loss of $550 000. This property is sprinklered in all the manufacturing parts, and in all rooms where there is moving machinery; in fact, practically throughout, except in some storehouses, rolling mills, and foundries. Of the 450 fires, 378 had a loss of less than $1 000 each, 59 less than $10 000, and only 12 over $10 000. Now, when we remember that textile mills form a large part of this property, many of them working cotton, we see what protection does.

Considering those fires which cost over $10 000 — in one the sprinklers were shut off by accident; in another the public fire department put hose streams in after the fire was really subdued, and made a very large water loss; in a third case the fire was in a jute storehouse, jute being very subject to water loss, and the water went down through several stories, making a heavy water damage; in a fourth case the gas connection broke near the meter, and gas came out and played against the ceiling for over an hour; there was no outside cock which could be found, and the gas was n't shut off until the gas men came and dug up the street and turned off the gas with a monkey-wrench, and all that time the water was pouring into the building, but the sprinklers held the fire in check. Eight of the twelve fires causing more than $10 000 loss were in unsprinklered storehouses, foundries, or rolling mills. So I think we have very clear proof of what protection does; and I think we can safely say that when a town invests its money in a water department, and allows the free use of that water on private fire protective apparatus, under proper restrictions, it is doing something which will give the protection it desires.

One more thing. I wrote to a number of superintendents and I have received replies very promptly, for all of which I am very much obliged. The reports from thirty-eight towns and cities showed that in thirty-one no charge whatever is made for water for fire purposes; a charge is made for laying the fire service connection, but no annual charge for water or for having the service ready to be used in case of fire. In seven a charge is made, but in six of those cases there were private companies. My inquiries covered New England, New York, and New Jersey, as far as I could make them in the very short time I had, and I think that the returns are a fair indication, perhaps, of what the general practice is.

Just one more word as to this matter of water being improperly

used for mill purposes through fire connections. We have hoped that some method might be found to obviate this other than by putting meters on the fire supplies. We have always tried to get rid of meters. One way which has been adopted, I think with a good deal of success, in Providence, and is being taken up in New Bedford and Fall River and in some other places, is to seal all the hydrants, using an ordinary lead seal such as is used on freight cars, and then having it understood that these shall not be broken except in case of fire, and then the water department shall be notified within perhaps twenty-four hours. When insurance inspectors wish to test the public water supply, about once a year, as is the practice, the water department furnishes a man to go with the inspector at a time agreed upon, and the seal is broken and resealed, and in some cases a moderate charge is made for the man's time. That, I think, is very fair and reasonable, and the only objection to it is that it prevents a mill manager from exercising his fire department here and there in the yard on a Saturday afternoon and putting on a few streams from his hydrants and using his pump; but the gain, where it is necessary to have some protection, is far more than the loss.

Of course where some type of metering device must be used, we have all been interested in some of the by-pass methods which Mr. Crandall has told us about, and which we and also some of the water meter people have been experimenting with. On this matter we hope a little later to have some data of interest. But we prefer to get along without anything if we can, and to try to lay out a fire system so simply that all the pipes can easily be traced, and the water department inspector can make sure that there are no improper connections, and then if it is believed that further precaution is necessary you can seal the hydrants and sprinkler drip-valves. But we very much hope that the policy of annually charging for services used for fire purposes will not become general; and I think we can all see that should it become so it would tend to discourage the investment of private money in private protective equipments, which are very much more efficient than anything which can be secured from outside hose streams only.

Mr. Hammond. I made no complaint about stealing water — you may possibly know the location where I live, being an insurance man. Each mill has direct connection for fire streams without a meter, and they have a separate system metered. They are all will-

ing to pay, but the question is, What is a fair basis for us to charge on? Bear in mind that our corporation is a private company, and we give the mills all the hydrants they want; but I say it is not a parallel case to a public water supply of a city, for they can tax the citizens to make up for any deficiency.

THE PRESIDENT. I think it would be well to continue this discussion at our next meeting. I have no doubt many of you would like to make some remarks on this subject, and if there is no objection we will have it on our program again at that time.

[Continuation of Discussion, March 3, 1901.]

PRESIDENT F. H. CRANDALL.* At our February meeting, the discussion of the subject "Charges for Private Fire Pipes" had progressed but a short way when, owing to the lateness of the hour, it became necessary to adjourn.

A case was then presented where the cost and value of protection afforded by private fire pipes was recognized. There was no difference of opinion as to who were the parties benefited, nor was there any desire to assess the cost of the protection upon others than those directly benefited. In short, the mill people, who derive their fire protection, both public and private, from the water works (for the former, the town pays at the rate of twenty dollars a hydrant) are the owners of the works. They have become convinced of the necessity of increasing the receipts from private fire protection, and are considering how the increase can be most equably apportioned.

A member, who had troubles of his own, spoke briefly and feelingly in regard to furnishing water to pipes supposed to be used for fire purposes only.

Another member, presenting the insurers' view of the case, called attention to the facts that every dollar paid by a mill corporation to any one else for fire protection lessened by just so much the amount which that corporation could be induced to invest in insurance premiums and improved fire protective appliances; that fire pipes might be kept entirely independent of, and free from, connection with other pipes; and that, if deemed necessary, assurance in regard to the use of such pipes for no other than fire purposes might be required, there being no mechanical obstacle in the way of secur-

* Superintendent, Burlington, Vt., Water Works.

ing information on that point without detriment to the interests of either of the parties interested.

The advantage to the public in general, which may and occasionally does result from the presence of automatic sprinklers, was clearly and forcibly stated. The damage which occasionally results from their presence, or, to be more accurate, the damage which occasionally results from the improper installation of such plants, was not mentioned. Neither was there much said in regard to the general tendency to meter fire pipes at the street line, as evinced by the practice in Philadelphia, Pawtucket, Portland, Norwich, and other cities. Nor was there much said in regard to rates charged for such service, as in Providence, Milwaukee, San Francisco, Newark, and other places, where the propriety of making assessment for such service is recognized.

Experience everywhere indicates that the improper use of services, relative to the use of which no means of securing reliable information is provided, is a natural consequence of their existence, and must be recognized as one of the conditions of the situation. Such use of such pipes is condoned, if not abetted and encouraged, by the community furnishing an unmetered and otherwise unsafeguarded supply.

The teacher who each night requests those of his pupils who have broken no rule to rise, and who at the end of the week rewards those who have risen each night, has little to say for himself when taxed with offering a premium on prevarication.

The housekeeper who, on account of shutting a hungry cat in the pantry, suffers considerable loss, finds small consolation in blaming the cat.

The water department, placing an unmetered and otherwise unsafeguarded supply on the premises of a taker, finds itself quite similarly situated.

Except in the case of public water works furnishing water for private fire protection, it is not as yet customary to rely upon customers to help themselves, and afterwards to tender a proper equivalent.

The fairness of any assessment, it goes without saying, is dependent upon the accurate determination of the benefit for which assessment is made. Schedule assessment for private fire protection may, under favoring circumstances, be based upon the number of automatic sprinkler-heads and other openings supplied ; upon the saving in in-

surance secured, or upon the amount of insurance carried. Either of these methods involves going to the customer for data upon which to make out his bill.

Over such methods, a method the data for which is to be found in the books of the water department, and which involves neither espionage nor reliance upon outside information, presents manifest advantages. The size of the branch and the class of service rendered together furnish a basis for such assessment.

The cost of furnishing water for fire purposes only to pipes in which a pressure slightly in excess of the water-works pressure is maintained, with a gong to automatically give warning of a drop of pressure, is very different from that of furnishing the same service to pipes on which there are no such appliances for the immediate detection of leakage or withdrawal of water.

The value as well as the cost of protection afforded by a properly safeguarded system of automatic sprinklers, by a system of hydrant or standpipe openings with hose attached, or by the latter system without hose attached, is in each case different.

To assess the benefit derived from private fire pipes, the first requisite is assurance in regard to the method of their use. If it cannot otherwise be clearly shown that they are used for no other than fire purposes, a meter rate with minimum clause, based on the size of the service, offers about the only equable method of assessment. This method is evidently growing in favor, as are meters in general wherever difficulty is encountered in arriving at an equable schedule assessment. The metering of such service without detriment to the interests of either insurer or insured, so far as interruption of water supply is concerned, is merely a matter of a few dollars. The inability of large meters to measure very small streams a small outlay also suffices to overcome.

It may to some, but not, I think, to the insurance people, seem an error to say that the insurance companies are more interested than the water companies in the prevention of improper construction and use of private fire pipes.

It is annoying to the water-works people to be obliged, yielding to the demands of influential taxpayers and insurance people, to grant applications for service calculated to place in jeopardy large interests. When the automatic sprinkler system, after having fulfilled its mission, absorbs the efficiency of the water works to no purpose, it is the insurance company, not the water company,

that is the heavy pecuniary loser by reason of the error in construction.

It is safe to say that whenever in dealing with the water-works people, loose or questionable practices prevail, the practice is not radically different in dealing with the insurance people. It is equally safe to say that where the pecuniary loss of the water works on this account may be measured in dollars, that of the insurance people runs into thousands of dollars.

The value of the water which may, without detection, be abstracted from fire pipes is insignificant compared with the damage which may result from apparatus so used being in consequence found out of repair in time of need.

The interests of water and insurance companies may, at times, seem to conflict; but in my opinion, aside from the possible insignificant curtailment of the amount invested in insurance policies, by reason of the amounts paid to water companies for services in that line, the interests of insurance and water companies are ever identical.

Under public ownership in many cases in the past, the benefit accruing to the general public from the presence of private fire pipes has been regarded as sufficient to warrant the assumption by the general public of the expense, usually regarded as insignificant, of furnishing water for fire purposes only to such pipes.

It often happens that the water takers of a community are willing to have the major part of the cost of public fire protection included in the water tax, and not infrequently the same class of rate payers, or the general public more or less indirectly benefited, are willing to contribute largely to the expense of private fire protection.

No case of a private corporation receiving from the general public remuneration for such service rendered to other private corporations has come to my notice.

Experience in furnishing water to pipes supposed to be used for fire purposes only has resulted in a considerable modification of the perhaps formerly generally accepted idea as to the insignificant cost of such service.

It at times occurs that either through a desire to secure the greatest possible revenue from the water department, or through a desire to obtain the benefits incident to the public ownership of a water plant at the lowest possible cost to the individual water taker, or for some other reason, public sentiment, or some equally potent force,

demands that whenever a service is obtained of the water department by a private corporation or individual, an equivalent shall be rendered.

It is to the situation resulting from these latter conditions, to the case where there is neither tax levy nor generously disposed community of water takers to fall back upon, that our attention is now invited. "When necessary to assess the cost of private fire protection upon the parties directly benefited, how can the necessary assessment be most equably apportioned?"

I hope, gentlemen, I have succeeded in saying something you will object to, or that will induce you to say something on this subject. I will call on Mr. Walker.

Mr. Charles K. Walker. There is something about this insurance business I don't quite understand. For instance, some four or five years ago a document was presented to our water commissioners by some of our mill people stating that they had been told by the insurance folks that the water supply was inadequate for fire protection. The complaint came from two mills. Within two or three hundred feet of one of those mills there were five or six hydrants, and yet the insurance people had told them they had not sufficient fire protection; and the other mill was about six hundred feet from the hydrants, and they said they had been told by the insurance people that they were not sufficiently protected. In both of these cases they were supplied from the Amoskeag Reservoir and also from the city reservoirs. When the Amoskeag supply gave out they would come to us and say, "We want you to turn on the water from the city, because they are going to mend the other pipe," or something of that sort; and so we would go and turn the water on for them that they might not be without a water supply, and they have had that right along.

This was in 1896. The commissioners voted that if the mills would pay the six per cent. on the cost of the extensions required to go where they wanted the pipe put, they would put them in the ground the same as for individuals. Nobody has ever said a word about it since.

Now, the mills felt that they had supply enough, but it was the insurance folks who wanted a better supply. One of them came here last year and told us how to fix the gates. Well, there was nobody said a word in reply but friend Thomas from Lowell. The rest of us did not say anything, because we did not know but we

had done our duty right up to the handle. It seemed that Brother Thomas had too, but still he felt that he had got to tell these insurance men that he had. And so they come here year after year and tell us what we ought to do, and they come to the city and they say what size of pipe we have got to lay. It seems there is n't anybody who knows what size of pipe to lay except the insurance folks. There can't any living man tell me why, if a mill has this fire protection and sprinklers, they should not pay the city or the private corporation for them. I hope there are some of those fellows here to-day who will get up and try to tell me that.

They go on the ground that the mill is doing a good deal for the city, and that they are doing so much for the city that they ought to have the water for these sprinklers for nothing. But where are you going to stop if you work on that theory? You make the city pay for hydrants, and there are five or six of these hydrants with seventy-four pounds pressure within two hundred feet of one of these mills, and yet they said that they were afraid they had not water enough. Well, they did not want any more hydrants enough to pay for them. That is where the trouble is, and I am here to protest against giving these people everything for nothing.

If some of these water commissioners or some of the insurance men or some other fellow who can talk better than I can will get up and tell me why we should supply a mill with water unless we get pay for it, I should like to have him do so. My idea would be to have a meter on every place where they have these supplies, and then if they want to take the water let them take it and pay for it; and if they have a fire we will deduct what water they use in putting out the fire. But I do not think it is fair for us to fill their pipes and keep them full and not get any pay for it. Now, I am afraid I shall talk too much on this subject, — I talked about it all the way home the other day, — and I do not want to say any more on it; but I want to have somebody tell me why the city or private water works should furnish water for these people and not get any pay for it.

The President. I understand that Mr. Pope is here representing the insurance interests, and we would like to hear from him.

Mr. Macy S. Pope.* I would like to ask Mr. Walker what kind of a meter he would have, with 75 pounds pressure, and when they are drawing water for a fire.

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* Inspector, Associated Factory Mutual Insurance Companies.

Mr. Walker. We have n't any meters; I wish we had.

Mr. Pope. You have meters on some of your mills up there.

Mr. Walker. Not for fire, not for fire, young man; it is only for drinking water.

Mr. Pope. Is n't there a meter at the Hosiery Company?

Mr. Walker. Not that I know of. I never saw one there, or heard of it, and nobody else.

Mr. Pope. Four years ago, when I was there, they certainly had a meter on the by-pass.

Mr. Walker. Well, that might possibly be for the corporation. The Amoskeag Reservoir furnishes them with water, and that we have nothing to do with; but we help them out in case of fire.

Mr. Pope. Are there meters on the Amoskeag water?

Mr. Walker. They have got them on the Amoskeag water, but we have n't any.

Mr. Pope. The objection the insurance companies have to the use of meters on the fire supply is that as soon as you make any considerable draft through them the pressure is much reduced. I think that subject has been discussed here a good deal, and you probably all have the figures in your mind. So far as making a charge for the water is concerned, that probably remains to be settled between the mills and the water-works people. They can fight it out among themselves, and it does not interest the insurance people except indirectly. The use of meters, however, does interest the insurance people because it reduces the pressure to such a large extent that the fire service is very often seriously injured. If you will design a meter which will not reduce the pressure, then the insurance people may take a different position in regard to it.

I would like to ask to what extent water is stolen from the pipes, that is, where they are actually tapped into and water taken from other openings than the openings which are supposed to be used for fire protection only.

Mr. Walker. I wish I could tell you, but I can't, for we don't always catch them. I know, though, that there is some.

Mr. J. Waldo Smith.* This matter of the proper price to be paid for fire service in a mill always has been a bone of contention between the mill owners and the private water company. I speak from the private water company's standpoint. The mills always claim that they should not pay anything for having hydrants all over

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* Engineer and Superintendent, Passaic Water Company, Paterson, N. J.

their yards and sprinkler systems all through the mills and that it is n't worth anything at all to them.

To answer the question asked by Mr. Pope in regard to how far they go in taking water without authority, I will say that in Paterson, Passaic, and Montclair, N. J., I don't believe there is one fire service from which the water has not been used contrary to the rules of the company. The only thing that will stop them is to put on meters and make them pay for all the water which goes through the meters. It has seemed to me that the best way to do was to charge a minimum rate, according to the size of the fire supply, and allow the mill to use up to that amount, and then if they use more, pay for it at the regular meter rate. The minimum rate would represent what the water company could afford to furnish that amount of water to the mill for.

It seems to me that some of the meters of the rotary class are so constructed that the head is not seriously cut down by a very large flow, and I would like to ask Mr. Pope, or any insurance man, what devices they have for preventing mills from, I won't say stealing water, but accidentally taking it? They always say it is an accident, and they are very sorry, but you may observe that they are never very severe on the man who causes the " accident."

Mr. F. N. Connet.* There are two incidents which lead me to think that water is sometimes taken from the fire service without being paid for. In our plant in Providence we make a great deal of hydraulic apparatus, and some time ago we had to test some of it at a much greater rate of flow than the ordinary water pipe connected with our manufactory would allow, and so we got permission to use the fire service for five minutes. After we had done so, we reported how much water we had used, and, as it happened, we reported to another man. The fact that we had reported, and so accurately, seemed to surprise him, and he was so pleased that he said he wouldn't charge us anything for the water. That is one incident.

Another case was in another city, within fifty miles of Boston, where there were at least half a dozen fire service connections, and the water company was assured that no water was being taken through them; but one day the superintendent of the water works thought he would test it, so he shut off one after another until only one remained open, and finally he shut that off and looked up at the mill; and in about two minutes there were about a hundred men

*Engineer, Builders Iron Foundry, Providence, R. I.

sticking their heads out of the windows to know what had happened, where the water was. I can't explain it, but perhaps some of the superintendents here can.

The President. Will you not say something in regard to measuring devices which are supposed not to interfere too seriously with the pressure?

Mr. Connet. There are meters and meters. We all know that if we draw a curve representing the resistance that is offered to water by any meter, letting the vertical elements of the curve represent the resistance and the horizontal elements represent the velocity of the water through the meter, with some meters the curve will be almost horizontal until it gets up to about the capacity of the meter, and then the curve suddenly changes and goes almost vertically. Well, a water meter having a curve of resistance of that nature is certainly a very dangerous thing to place on any fire connection. But there are some other meters — at least one — where the curve is not of that nature; it is a gradually increasing curve, where the resistance varies almost exactly as the square of the flow. In other words, a meter having moving parts will have a curve of resistance of this undesirable nature that I mentioned first, whereas a meter not having any mechanical parts, and one through which the water flows without turning any corners, will have a curve which need not be objected to by the insurance people, and I understand they do not object to it. I am not mentioning any names.

Mr. J. C. Hammond, Jr.* This discussion has drifted somewhat from the line of the question as it was presented at the last meeting. We have a separate connection for fire direct from the main, and there is no water taken through it except to supply the sprinklers; there is a separate connection for all other purposes, on which is a meter. Now the question I raised in the first place was, what was a fair basis on which to make a charge for the use of water. At the last meeting Mr. French argued that no charge should be made, or only a nominal charge. That is all right if you have got a city to tax, but in the case of a private company, with bonds coming due in the future, we have got to look after our revenue, and it is no more than fair that we should have it. We laid a twenty-inch main to supply water for fire purposes to these various establishments, when a main half the size would answer for domestic purposes. They don't steal water in Connecticut, so this talk about the trouble in

* Treasurer, Rockville Water and Aqueduct Company, Rockville, Conn.

New Hampshire and Massachusetts of course does n't apply to us. But I will say this, that if anybody will stop to think of it for a minute it will be apparent that if there is any circulation of water in the sprinkler pipes, either in cold weather or in summer, the pipes will drip. If the water is not drawn it remains in the pipe at the temperature of the room; but if you draw any water out of it, and thus make it either warmer or colder, you will have a drip. We sometimes do find that, but it is always an accident.

Now the question is, How much shall the mills pay? The insurance people say we must n't do anything to drive the manufacturing concerns out of the place. That is all right. But if a man has got a cow down at the lower end of the town, he has got to pay for water for the cow and he has got to help pay for the hydrants to protect his house; while the corporation at the other end of the town can save largely in its insurance, reducing the rate from three per cent. down to one per cent. and then getting a dividend of anywhere from fifty to ninety per cent. back on that, and not pay anything; and the insurance people say that is as it should be. Now, I live in a hard cider country, and a fellow there made some cider just before the agricultural fair, and one of his neighbors suggested that they make a lot of money on cider. Said he, "You make up a barrel of cider and take it down to the fair ground, and I will furnish a faucet, and we will go halves." Now, if we will only furnish the water, the insurance people are willing to get the benefit of it. I think we had better go into the insurance business ourselves, or else have them provide some way for us to get a revenue from the water. It is a benefit to them to have us furnish it, the parties who have it acknowledge it is a benefit, and really the only question is, What is a fair basis on which to charge for it?

For instance, one establishment is a large cotton mill, where the risk is great; another is an envelope works, another a silk works; the raw materials are more or less combustible, more so in one case than another, and one has much larger interests to be protected than another. Now one plan would be, if we wanted to raise five hundred dollars or five thousand dollars, to take the amount of insurance which these several mills carry and then reckon a percentage on that to raise our revenue. Then a man who has a mill filled with valuable machinery, and who carries a large insurance, and who wants fire protection, can pay for it in proportion to his insurance. The fact that we are furnishing water for his sprinklers saves him a large

amount of insurance, and he is really willing to pay for it, — or he ought to be, — and the question is to determine what he shall fairly pay; and I asked the question in the first place thinking some of you gentlemen could suggest a fair way to assess it. At present each mill pays one hundred dollars. One mill will carry six or seven hundred thousand dollars of insurance, and another carries fifty thousand dollars, and yet each pays one hundred dollars. Some of them we have to furnish water to by pumping for the high service, and yet all pay the same price. It is n't fair, and they know it is n't fair; and I should like to find out, if I could, some plan on which each should pay its proper proportionate part, and I think they would be willing to do it.

Mr. Pope. I think the gentleman misunderstood the argument advanced by Mr. French at the last meeting with regard to charges by private corporations. I did not understand he thought that private corporations should not receive compensation for the water they furnish, but, reasoning in a logical way, he argued that it belonged to the municipality to pay for the fire service rather than for the mills to pay for it.

Mr. Hammond. Possibly so, sir; but I understood him to say that the corporation might make a merely nominal charge.

Mr. Pope. His argument was that the mills paid their general taxes the same as the householders pay their taxes.

Mr. Hammond. Does the public save anything on the insurance the mills have to pay?

Mr. Pope. No; but the public pays for the security just as the mills pay.

Mr. John C. Chase.* Did I understand the gentleman from Connecticut to say that the Connecticut water consumers are so honest that they never steal water?

Mr. Hammond. One minister did, — a Congregational minister, too.

Mr. Chase. He was n't a Baptist?

Mr. Hammond. No. We give them all they want. The gate was off in front of the parsonage, and the minister had his horse in the yard feeding, while he was running the lawn mower, and he placed the garden hose in such a way that it played right across the gateway and kept the horse from going into the street, making a new kind of water gate.

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*Civil Engineer, Derry, N. H.

Mr. Chase. The only comment I was going to make was that if the Connecticut people were as honest as our friend would seem to imply, I thought it was unfortunate we could n't import some of them into some other States, — New Hampshire, for instance.

Now, as throwing a little light upon the subject under discussion, I would say that, as far as the corporation which I represent is concerned, if any consumer who wants a private hydrant will pay one hundred dollars a year, he gets a privilege of having a large connection, four- or six-inch, and maintaining fire hydrants and sprinkler service, and he is also permitted to have the use of one hundred dollars' worth of water per year, or more if he chooses to pay for it, measured through a meter. In fact, the fire protection is thrown in as a bonus to any one who pays one hundred dollars a year in water rates, if he chooses to maintain a system of fire protection himself. As we look upon it, the city pays us a round sum for fire protection, and it is immaterial to us whether they use the water in case of fire from their private pipes or from the city hydrants. The only trouble we have is in getting them to take the water only through meters, and I judge that that is a common trouble, from the remarks I have heard here. We have had no less than half a dozen cases of the grossest larceny in the stealing of water. In one of our largest cotton mills, after about two years it was discovered that they had deliberately made a cross-connection between the sprinkler system and the sanitary pipes in the mill, and had been taking about all the water that the mill required for use through it. That was cut off, and we thought they had learned a lesson. But there was a change of administration, and we soon had reason to believe that they were again stealing water. They have a condensing engine, and the supply is drawn by a pipe running out into the river. A meter was set on the service on a Saturday afternoon and the following Monday it was learned that the mill was shut down on account of the suction pipe of the condenser being out of order, and we have reason to believe that we had been furnishing the supply for a long time previously. Since the installation of the meter our income from this consumer has materially increased with a much less draft of water.

Now, this question narrows down, I think, to one of two things, — either devise a meter which will measure the water in a way which is satisfactory to the insurance people, if that be possible, or else educate people up to such a degree of morality that they will not steal water. Which is going to be the easier thing to do, — to work

from the mechanical or from the moral standpoint, — I will leave it to you gentlemen to decide. But I don't know why we should have any particular love for the insurance people. They don't contribute to our resources at all. All we can do with them is to make use of them as a sort of club to make our customers a little more honest, telling them that if they want the water for fire protection they must only use it in a legitimate way, and if they won't do that, then they must fight it out with the insurance people.

THE PRESIDENT. Mr. Holden is called for, and we would like to hear from him.

MR. HORACE G. HOLDEN.* I don't know as I have anything to say in regard to this matter. I represent a private water company, and we are naturally anxious to get all the income we can out of our water works; and if any of our customers want water for fire protection we are always willing to give it to them, provided they pay the cost of putting it in. If they are not customers of ours we charge them the same rates that we charge the city. We have a good supply of water, so we are not disposed to curtail on any one.

MR. CONNET. I would like to say one thing more. It seems to me that it is a mistake to assume that water companies have but one thing to sell, and that is water. They have two things to sell: one is water, and it is easy to measure that; the other is security against fire, and it seems to me that that should be paid for as willingly as any other form of security. It should be paid for as willingly as a premium on an insurance policy. Fire protection seems to me to be a sort of insurance in itself, and if a four-inch pipe is put in for fire protection it ought not to be a very hard matter to collect a minimum rate just about the same as the minimum rate for a four-inch pipe on any other branch of the service. It is insurance and a security which the consumer should be willing to pay for. Let us not forget, then, that the water-works companies have two things to sell.

MR. WALKER. I am afraid our friend from Connecticut will have to go back home without any information. He has asked how much would be fair, but I do not believe there is anybody who will get up here and tell him. He will have to take the members one side and ask them privately. I do not know what would be fair. It is according to where you are, whether you have to pump, and so on. But I should like to have him get all he can out of the insurance

*Superintendent, Pennichuck Water Works Company, Nashua, N. H.

companies. I want to be fair with everybody, including the insurance folks, and I would like to give our friend the information he wants, but you know you cannot always tell what to do, because there are so many different opinions about the matter. It seems to me that he has got one thing right, and that is that he should be paid a fair compensation. If he has a gravity system he can afford to do it cheaper than he could by pumping. We have to pump our water. But what looks fair to me is to use the Venturi meter, which these fellows come along and tell you about. They say it does not reduce the pressure a mite, — I do not know whether it does or not, — but it is so short that they say it does not make any difference in the pressure if the pipe is contracted. That is what they argue to me, and that is what their circular says. Now, if that is so, why not put on a Venturi meter and satisfy these insurance folks?

Dr. George W. Field. The condition which Mr. Walker has described as obtaining in Manchester reminds me of a story, which may have originated there, about a man who built a very handsome house high up on a hill, where people saw it and often remarked upon it. Two men were going by in a car one day, and one of them remarked on what a magnificent house it was. His companion replied, "Yes, it is a fine house, but rum built it." The owner of the house happened to be sitting in the car opposite the gentlemen, and he said, "Beg pardon gentlemen ; I built that house. I sell rum and water. The rum just about pays for itself ; that house was built on water."

Prof. William T. Sedgwick. It seems to me that this Association ought to have from time to time, and it does have from time to time, committees appointed to investigate and report upon just such questions as this. The rest of the country looks to the New England Water Works Association for points of progress. Now, here are a lot of opinions, complaints, practices, and so on. The whole question is a serious one, because the quantity of water which is supplied in a city is all the time demanded to be larger and larger, and it is getting to be a problem where the water supply of our cities is going to come from by and by. The quality of water has been improved, the private companies and the public authorities have done their best to improve it, and it is only fair that those who use the water should pay for it. That is admitted. But it is said that some basis ought to be determined upon for a proper compensation.

Now, this Association, it seems to me, could not do a better thing

than to appoint a committee, whose first duty would be to get at the facts on this subject. What are the facts? Is water stolen to any considerable extent, and if so, what action is needed, and how can that action be coördinated with the requirements of the insurance companies so as to meet the ends desired? It seems to me, as I said in the beginning, that the Association ought not merely to hear complaints and general suggestions, but should have a committee to look into the facts, and to make a report which would be valuable from this time on.

This interests me very much, because it is one of the questions affecting the consumption of water, and every sanitarian is interested nowadays in the problem which is so nearly before us, — What are we going to do to obtain the vast quantities of water that are required? We have got to do something. At present we are keeping up the quality and furnishing any quantity. That cannot go on forever. We have got to do something, somehow or other — perhaps put in a double system, perhaps put on more meters, or do something else, I do not know what. It seems to me that this Association ought not merely to discuss this matter, but should have a committee to investigate and report upon it. I do not make a motion that such a committee be appointed, because I do not know enough about the subject; but it has occurred to me as I have been sitting here that that is the proper thing to do, — have a committee which shall get at the facts, digest them, and make a report, and then you can discuss the report and adopt it if you see fit.

Mr. Byron I. Cook.* I think Professor Sedgwick's remarks are in the right direction. Almost every water-works superintendent who has a fire supply running into manufacturing establishments has at one time or another caught them using the water improperly; and I do not know as it can be helped. They say, "We got into trouble and we had to have some water, and we did not suppose you would miss a small amount." And I really think we shall not arrive at any satisfactory solution of this matter until the insurance people and the water people get together. We want help from them and they want help from us. It is a mutual thing. Acting upon Professor Sedgwick's recommendation, I will move that the President appoint a committee of five to consider this subject, and to report at a future meeting of the Association.

The motion was adopted, and later the President announced the

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* Superintendent, Woonsocket Water Works.

committee as follows: Byron I. Cook, Edward V. French, J. C. Hammond, Jr., Charles K. Walker, and John C. Chase.

Regulations of Various Cities.

The following is the report of the meeting of the New Bedford Water Board at which the regulation of the use of private fire supplies was decided upon.

After the ordinary business of the meeting had been transacted, Superintendent Coggeshall read the following report: —

To the New Bedford Water Board:

Gentlemen, — At a meeting of this board held on September 6, 1900, the following vote was passed.

Voted, That the superintendent be instructed to lay before this board as soon as possible plans of the various mill supplies of this city, indicating thereon how the same can be completely metered in each case.

In compliance with this order, I would respectfully report as follows: —

Plans showing the piping system in each mill enclosure in this city are upon file in this office and are subject to your inspection.

It is customary in planning mill water supplies to divide said supply into two portions after it has entered the mill premises. Each portion has its distinct line of piping. One is intended to be used wholly for fire protection, the other to supply the daily manufacturing and domestic use. In the later built mills the fire supply is again divided into two distinct parts,— that for hydrant use and that for sprinkler supply. This enables either to be operated entirely independent of the other. Unless this be done, a break in the sprinkler system, such as would be occasioned by falling walls in case of a fire, would also cripple the hydrant supply.

Each mill has capacious steam fire pumps, which admits the pumping of salt water from the river into both sections of the fire pipe system. Check valves properly placed on the mill piping system make it possible for said pump to cause the water pressure to exceed the usual city water pressure. More effective fire streams are thereby obtained. The mill system is supposed to depend upon the city supply for only the earlier moments of a fire or until they can get their own pumps into full operation, when they will furnish the entire supply to their own system, leaving the city supply wholly for the use of the city fire department.

These systems vary from a simple one-pipe affair to the elaborate three separate pipes with connections to the pipes of adjoining cor-

porations, thus providing a way to obtain additional pump service in case of need.

It has been customary in all cities to allow the placing of unmetered pipes from the city mains into private property, with the understanding that its use is to be confined wholly to fire protection. The interests of water departments and insurance companies seem to conflict when it comes to the metering of the fire supplies. The insurance people claim that meters obstruct the flow and destroy the efficiency of the fire streams, especially should they get stuck. This is true of most of the types of meters. There are, however, exceptions to this statement, and meters can be supplied to which this objection will not apply.

The testimony of all cities agrees that private hydrants will be used more or less for purposes other than for fire protection, unless prevented by some form of restriction.

Here in this city no restriction is placed upon the use of the hydrants, other than the mill authorities know that they were allowed simply for fire protection, and not to be otherwise used. But there they stand, with the opening wrench close at hand. Any employee can open one and obtain a supply. He may give the matter very little thought other than he wants the supply for some purpose ; and as the hydrant is conveniently placed, he goes and gets it without perhaps even informing the mill office. Water carts are filled, or a hydrant stream is used for a few moments to lay the dust; or perhaps a supply is wanted for some building purposes, or numerous other supplies may be needed. It is not denied that the hydrant water is used when the occasion presents itself. The most serious use has been the taking of large volumes for condensing purposes. This is done when a low run of tide in the river deprives the mills of their usual salt water supply. With one or two exceptions they have failed to provide an ample secondary supply to meet an emergency like this, so, as the matter now stands, they must at such times either use the hydrant water or stop portions of the mill. Such large volumes have been taken on several occasions for this purpose that for the time being the supply to a considerable portion of the elevated part of the city has been entirely cut off.

During the past year four of our corporations report that they have on several occasions used hydrant supplies for this purpose. In the absence of any rate for this purpose the manufacturing rate has been charged. The amounts charged upon the data supplied by these mills were $429, $259, $50, and $24. No reports of a similar use have been received from the remaining corporations.

Other cities have had this same question to contend with, and their experience may be of value to you.

Fall River has had an experience similar to that in this city. They allow an unmetered fire pipe, the supply from which is to be used for no other purpose except fire protection. The use of city water for condensing purposes is not allowed. Every time a hydrant is opened

except for fire purposes or they detect a supply being taken from the fire supply pipe they impose a fine of twenty-five dollars for each and every offense. They are of the opinion that the time is rapidly approaching when the metering of all manufacturing supplies will be an absolute necessity, as they lately have had several occasions when they have been obliged to impose this fine.

Providence has had similar trouble, and it has resulted in the establishment of an elaborate set of rules, a copy of which I submit with this report. The points which will be of most interest to you are as follows : —

They allow unmetered pipes for fire supplies, but every gate, valve, fire plug, or hydrant is sealed by a water department inspector.

All tests must be made in the presence of a water department inspector, who removes and replaces the seals, and a charge of three dollars for the first hour and one dollar for each additional hour is made for this service.

The seals may be broken only in case of a fire, of which written notice must be sent to the water department office within twenty-four hours after its occurrence.

No connection with any other supply is allowed. This prohibits the connecting of an auxiliary steam pump to operate another supply against a check valve, as is the case with the salt water pumps used in this city. Singularly enough, I am informed that this rule was adopted as the result of the failure of a check valve at a mill fire in this city some years ago, whereby considerable salt water was forced into the city mains.

There are several other provisions which are not of as much interest at this time. The penalty for the violation of the whole or part of any of these rules is from five dollars to fifty dollars for each offense, or be subject to having the supply shut off.

The experience of Pawtucket does not differ from the cases that have been cited. As a rule they have allowed an unmetered fire pipe, but they place seals upon all unmetered fire fixtures, the same as is done in Providence.

The water department inspector is present at every test, and removes and replaces the seals. For this service a charge of three dollars is made.

Some of the corporations insisted upon using the hydrants, and it has resulted in placing meters upon their supplies. After this was done no objection was raised against the use of the hydrants, as these mills were charged at fixed meter rates for all the water used. One of the largest corporations heretofore paying $3 500 for their yearly supply has taken the past year through a metered hydrant pipe water to the value of $5 700.

Large meters, with their necessary fittings and the placing of the same, are very expensive. To completely meter all the mill supplies would require the placing of a number of very large meters, and would involve an expense of nearly $30 000. A much smaller meter

has ample capacity to meet every daily requirement aside from fire and condensing supply.

If the hydrants are to be allowed to continue to supply water for condensing use or for any other foreign purpose, then that supply ought to be metered and a rate fixed for that use. Other than this, the adoption of a modification of the Providence rules, whereby all fire apparatus is to be sealed, would entail comparatively little expense as compared to the placing of the large meters.

Both Providence and Pawtucket report the results obtained by the sealing process to be very satisfactory.

R. C. P. Coggeshall,

Superintendent.

The superintendent's report was adopted, and Mr. Pease introduced his order, as follows: —

Hereafter private fire supplies are to be allowed only upon the following conditions: —

I. All hydrants, fire plugs, valves, etc., necessary for private fire protection, which are supplied by an unmetered connection with the city mains, will be allowed under the condition that they remain sealed; and no water shall be used therefrom excepting in case of fire.

II. The seals shall be placed by a representative of the water department, and shall be removed only by a representative of the same department, excepting in case of fire. In such cases written notice shall be sent to the office of the water board within twenty-four hours after its occurrence.

III. No connection of pipes whereby the water from the fire pipes may be delivered into those furnishing the daily supply will be allowed. This applies to fire pumps where, by connecting its suction with the city water pipes of one system, delivery may be made into the pipes of another system.

IV. In case a fire supply is metered, the sealing of the different fixtures will not be considered necessary.

V. Tests of private fire supplies may be made by the owners thereof, or by insurance inspectors. It must be done in the presence of a water department inspector, whose sole duty will be to remove and replace the seals used on the fire apparatus and note the time required in making the test.

VI. Notice is to be given in advance at the office of the water department whenever a test is desired, when a date and hour will be agreed upon.

VII. All check valves upon the main supply pipes shall be inspected and overhauled by the superintendent at least once a year, and oftener if he considers it necessary.

VIII. All expense of inspection and repairs shall be charged to the party supplied.

IX. The penalty for violation of either of the above sections shall be the extreme penalty provided by the city ordinances for cases when openings or connections are made with the city water pipes without the authority of the water board.

Mr. Pease moved the adoption of his order.

"I don't want to be considered as opposing this order," said Mr. Hunt, "but it's an important matter, that I think we ought to take time to look the thing over and study into it. The report and the order are so extensive that it's a difficult matter to take it in at one reading."

Mr. Pease replied that the subject had been up for several months, and that the board knew as much about it then as they would ever know. The superintendent, he said, reported that hydrant water was being misused, and this was the most practical method of stopping the practice. It entailed no hardship on the manufacturers, but merely provided for seals so that they could not use water that they did n't pay for.

Mr. Hunt admitted that the matter ought to be adjusted. "I think," he said, "that the mayor has given this question of water rates and water supply considerable study, and we ought to wait for a full board. It would be better to take a reasonable time, so as to be acquainted with all the particulars and vote intelligently. I therefore offer an amendment that action on the matter be postponed until the next regular meeting, or a special meeting to be called by the mayor or the superintendent."

Mr. Pease declined to accept the amendment.

Mr. Hunt said he thought that the mill men ought to be given a chance to be heard.

To this Mr. Pease replied that he did not believe the mill men wanted to be heard. It was a question of stopping the stealing of water, and he asked Mr. Hunt whether he would want to wait and give a hearing to a man caught robbing a money drawer. Mr. Hunt thought it would depend.

At this point Mr. Taber seconded the motion to adopt the order, and on a vote Mr. Mason declared it carried.

The water rates of the city and county of San Francisco, Cal., adopted by the Board of Supervisors, June 2, 1897, provide : —

SECTION 9. *Fire Pipes.* — Meters shall be applied to all pipes used specially for fire protection, and monthly bills shall be charged for the same at regular meter rates, provided, however, that the monthly

bill shall not be less than fifty (50) cents for each one-half (½) inch diameter of pipe used.

Rules for the Use of Private Fire Supplies.

Providence Water Works.

Applications for private fire supplies must be accompanied by a full detailed plan, showing all connections contemplated with other fire supplies, tanks, and sewers which shall be approved by the city engineer before action will be taken thereon.

No changes, additions, or connections will be allowed except upon plans filed and approved in the same manner as with the original application for said supplies.

All work in connection with private fire supplies shall be done by a licensed plumber and under proper inspection, and all gates, valves, fire-plugs, and hydrants connected with such supply shall be sealed by the inspector when deemed necessary.

For the purpose of covering the expense of a proper inspection of the complicated systems of private fire connections now demanded, the following yearly rates will be charged, when Pawtuxet water is exclusively used for general purposes, viz.: —

For one (1) supply, $5.00.
For two (2) supplies, connected, but without auxiliary tank, $10.00.
Either one (1) or two (2) supplies connected to tank, $15.00.

When other water than that furnished by the City is used for general purposes, SPECIAL CONTRACTS OR LARGER ASSESSMENTS WILL BE MADE.

Private fire supplies and the fire apparatus connected with the same may be tested by the parties owning the same, or by insurance inspectors, under the following conditions: —

First. Notice to be given at the office of the commissioner of public works that such test is desired, when date and hour will be agreed upon for said test.

Second. All tests to be made in the presence of the inspector assigned by the commissioner, whose sole duty shall be to remove and replace the seals used on the fire apparatus and note the time required in making the test.

Third. The rates for testing are as follows: —

One hour or less, $3.00.

For all time in excess of one (1) hour, $1.00 for each hour or fraction thereof.

Fourth. Water shall not be used from any private fire supply, nor seals broken or removed, except in case of fire, written notice of

which is to be given at the office of the commissioner within twenty-four hours after its occurrence.

Fifth. Not more than two private fire connections from the city water mains will be allowed to any building or premises, except under exceptional circumstances, to be determined by the commissioner. The connections may be made from one or more streets if the building or premises fronts upon the same. No pipes, however, will be allowed to be laid across a street.

Not more than two private fire connections from the city water mains will be allowed to be connected together under any circumstances in any building or premises

When two private fire connections are connected together, a suitable check-valve must be placed upon each.

In conformity with the order of the Board of Health, no private fire system which is in any manner connected to the city water mains shall have any other supply of water. No valves of any description will be allowed as "shut-offs" to any other supply, as there must not be a possibility of any other supply of water to such pipes.

When a tank is connected to a private fire system which is connected with the city water mains, it shall be subject to the following conditions: The only water that will be allowed to be supplied to the tank will be the water furnished by the city. Said water shall be measured by a meter. The supply pipe leading to the tank shall be entirely independent of the fire system proper. It can be directly connected to the city water mains, or to a regular service pipe which supplies city water to the premises where the tank is located.

The outlet end of the supply pipe of a gravity tank shall be placed at least six inches above the maximum water line of the tank, and the supply pipe of a pressure tank shall be so arranged as to prevent the water in the tank from flowing back into the city water mains. Each tank shall have a suitable check-valve upon the pipe leading from it to the distribution pipes of the fire system, for the purpose of preventing water from flowing into the tank from the city water mains.

A gravity tank shall be roofed over and constructed to prevent rain, snow, dust, or any other objectionable matter from getting into it. Each tank shall have a manhole and permanent ladders arranged for convenient access to its interior, and shall have an outlet in its bottom, so that it can be emptied entirely independent of the pipes of the fire system. The interior of each tank shall be thoroughly scoured out at least once in twelve months.

All "drips" of fire systems, which are intended to empty into a sewer, shall first discharge into an open tank, the outlet pipe of which shall be deeply trapped and connected with the sewer in the usual manner.

Sixth. For each and every violation of the above, in whole or in part, the offending party, at the discretion of the commissioner, will

be subject to a fine of not less than $5.00 nor more than $50.00, or be subject to having the supply shut off.

Owners or agents of property protected by private fire supplies shall cause copies of Rules one to six to be kept posted conspicuously in their office, engine room, and upon each floor of any building where fire-plugs are located that can be used by any employee; and no plea of ignorance will be entertained by the commissioner.

PROVIDENCE, R. I., September 14, 1897.

PRELIMINARY REPORT OF THE COMMITTEE APPOINTED MARCH 3, 1901.

[*Presented by Byron I. Cook, Chairman, September 18, 1901.*]

Your committee appointed to report on the subject of "Apportionment of Charges for Private Fire Protection, and the Means of Controlling the Supply Thereto," have not had sufficient time to fully consider all the points relating to this question. The committee have had one meeting, at which there were present, Messrs. French, Chase, Hammond, and myself. It was suggested that Mr. H. A. Fiske, Manager Underwriters' Bureau of New England, be asked to confer with the committee, which he kindly consented to do. As Mr. Fiske is now a member of the Association, I will later move that he be made a member of the committee.

The questions submitted to your committee in the advance discussion, namely, —

First. Whether the opportunities for the taking of water without the knowledge of the water department afforded by the presence of private fire pipes are frequently taken advantage of or no;

Second. Whether the benefit to the general public from the presence of private fire pipes is sufficient to warrant the assumption by the general public of the expense incident to furnishing them with water or no;

Third. Whether the service rendered in supplying water for fire purposes only to private fire pipes merits compensation or no;

Fourth. Whether securing assurance of the use of private fire pipes for such purposes only is merely a matter of a few dollars, and may reasonably be required or no;

Fifth. Any other facts in regard to private fire pipes, the manner of their use, the value and cost of the protection afforded, upon

whom and how the cost of such protection should be assessed, etc., which the committee may see fit to present;
were considered.

As to the first, it was the opinion of the committee that this question admitted but one answer; that private fire pipes are frequently used for other purposes than fire protection.

The second and third questions have only been discussed in a general way. It has been suggested that a basis for charging for water for private fire supplies may be found in the number of fire streams that can be supplied at different pressures; this method has many advantages and is more equitable to all parties than a charge per hydrant or sprinkler head, but until further investigations your committee are not able to present any reliable figures.

The most important point in this whole question is, how can the water people be protected against the use of water from private fire pipes for other than fire purposes. Sealing of valves and hydrants, with the most rigid inspection, does not fully protect. This method is faulty as no means are provided to inform the water department of the quantity used.

I have no doubt that you will fully agree with me that cases are few where private fire pipes have knowingly been tapped for the purpose of drawing water. What the water superintendent wants is the amount taken and just compensation for the same, when "I wanted a little water so I just took it." This can only be settled by some form of measurement, and the water meter is looked to, to do the work. The meter for this purpose must be of low cost, and so constructed that it will not retard the flow of water. Pipes for fire protection will then have to be entirely independent of other supplies. Your committee is fortunate that a short time previous to their appointment, investigations were commenced by the inspection department of the Factory Mutual Fire Insurance Companies of a form of proportional meter. As these experiments are still in progress and as your committee can have the benefit of the results, it would seem best that a final report be not made until these investigations are completed.

It is the intention of your committee to submit, if possible, a final report based upon reliable data and one that will be acceptable to all parties interested, as the best way to adjust this question. The supplying of water for private fire pipes is one of the most vexatious matters in water-works management, and I have no doubt that you

will agree with me that if the New England Water Works Association, through its committee, can solve this problem agreeably to all, it will confer a lasting benefit upon the water fraternity.

I will say that since the meeting of the committee I have resigned from active management of a water-works plant, and as my business in the future will not enable me to give much time to this important matter, I wish to be relieved from service as Chairman of the committee. I am willing to give what time I can as a member of the committee. I move that President Crandall and Mr. H. A. Fiske, who has to-day been elected a member of the Association, be added to the committee.

Adopted.

PROCEEDINGS.

June Meeting and Excursion.

Somerville, Mass.
June 12, 1901.

Through the courtesy of his Honor Mayor Edward Glines, and by invitation of Water Commissioner Frank E. Merrill, Vice-President New England Water Works Association, the day was spent in Somerville as their guests.

The following members and guests were present: —

Members.

Francis E. Appleton, L. M. Bancroft. Fred Brooks, Joseph E. Beals, G. W. Batchelder, C. H. Baldwin, G. A. P. Bucknam, E. J. Chadbourne, George Cassell, R. C. P. Coggeshall, Byron I. Cook, W. E. Foss, F. F. Forbes, A. D. Fuller, F. B. French, W. J. Goldthwait, W. R. Groce, H. F. Gibbs, F. W. Gow, A. A. Gould, Frank E. Hall, John O. Hall, J. C. Hammond, Jr., J. H. Higgins. H. G. Holden, Willard Kent, C. F. Knowlton, A. E. Martin, W. E. Maybury, F. E. Merrill, Thomas Naylor, J. H. Perkins, Horatio N. Parker, C. E. Riley, W. W. Robertson, H. E. Royce, P. P. Sharples, E. M. Shedd, Charles W. Sherman, H. O. Smith, G. H. Snell. J. J. Sullivan, W. F. Sullivan, H. L. Thomas, R. J. Thomas, W. H. Thomas, D. N. Tower, G. W. Travis, W. W. Wade, C. K. Walker, G. E. Wilde, G. E. Winslow, E. T. Wiswall.

Associates.

Barr Pumping Engine Co., by W. H. Bodfish; Builders Iron Foundry, by F. N. Connet; Chapman Valve Co., by E. F. Hughes; Coffin Valve Co., by H. L. Weston; Garlock Packing Co., by H. A. Hart; Hersey Mfg. Co., by A. S. Glover; Henry F. Jenks; Lead Lined Iron Pipe Co., by T. E. Dwyer; National Meter Co., by J. G. Lufkin and C. H. Baldwin; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; A. P. Smith Mfg. Co., by W. H. Van Winkle; Union Water Meter Co., by J. P. K. Otis; R. D. Wood & Co., by C. R. Wood.

Guests.

George E. Ames, Lowell; Fred A. Beals, Everett; Francis H. Boyer, Somerville; James S. Beal, Hingham; John H. Crandon, Chelsea; G. W. Cormack, Stoneham; C. N. Fairbanks, Boston; J. W. Goodell, Burlington, Vt.; H. A. Gorham, Boston; J. T. Inman, Attleboro; F. E. Jones, Somerville; F. A. Morrison, Boston; A. F. Nagle, Neponset; G. E. Pickering, Somerville; T. J. Perkins, Watertown; L. P. Stone, Natick; J. T. Stev-

ens, Braintree; F. P. Skinner, Rockville, Conn.; W. W. Trowbridge, Newton; E. P. Walters, Boston; L. K. Woods, Everett; W. P. Jones, Somerville *Journal;* E. L. Pease, Somerville *Citizen*.

Also the following officials of the city of Somerville: Mayor Edward Glines, Aldermen Watters, Wentworth, Gilman, Belcher, Vinal, Pike, Caldwell, Simonds, Lowell, Littlefield, Woodbury, Reynolds, Frye, Waugh, and Smith, Street Commissioner Pritchard, Building Commissioner Fuller, City Messenger Mann, Mayor's Secretary Warren.

Business Meeting.

City Hall, Somerville, Mass.
June 12, 1901.

Vice-President Walker in the chair.

Vice-President Merrill, Water Commissioner of Somerville, introduced Mayor Glines, who welcomed the Association to the city, in which he was seconded by President Vinal, of the Board of Aldermen. Vice-President Walker replied to these addresses.

Applications were received from the following: —

For Member.

J. G. Falcon, Evanston, Ill.; V. R. Hughes, Napoleon, Ohio; Charles Anthony, Jr., Buenos Ayres, Argentina; Francis H. Boyer, Somerville; J. F. Sprenkel, York, Pa.; F. H. Pitcher, Montreal, Canada; E. Wegmann, Katonah, N. Y.; C. A. Lowell, Winooski, Vt.; J. F. Gross, Jenkintown, Pa.

For Associate.

International Steam Pump Co., New York City.

On motion, the Secretary was directed to cast the ballot of the Association for the above applicants, which he did, and they were declared elected.

The business meeting then adjourned.

The itinerary for the day included visits to the following points of interest: —

Prospect Hill, the site of a proposed municipal park, where one of the most important forts of the American entrenchments was located during the siege of Boston, 1775–76; Central Fire Station, engine house, and fire alarm system; Central Hill Park and battery; the English High School; the Public Library; City Hall; the Central Club; the old Tufts House, the headquarters of General Lee in 1775–76; Broadway Park and Ten Hills Farm (Governor Winthrop's residence, 1631); Winter Hill; Water Department Building, where

lunch was served; Old Powder House; Tufts College; Mystic Reservoir, of the Metropolitan Water Works, where the party assembled and passed a unanimous vote of thanks to the Mayor and City Government of Somerville, and to Water Commissioner Merrill; the old Timothy Tufts House on Elm Street; Spring Hill; and the works of the North Packing and Provision Company. At this point the party was received by Mr. Charles A. Cushman, General Manager of the Company, and shown over the works, and was further entertained by a luncheon, at the conclusion of which an enthusiastic vote of thanks to the Company and to Mr. Cushman was passed.

PROCEEDINGS OF THE TWENTIETH ANNUAL CONVENTION.

September 18, 19, and 20, 1901.

PORTLAND, ME.,
September 18, 19, and 20, 1901.

The twentieth annual convention of the Association was held in Portland, Me., on Wednesday, Thursday, and Friday, September 18, 19, and 20, 1901. The headquarters of the Association were at the New Falmouth Hotel. The opening session of the convention was held in the Council Chamber of the Portland City Hall, where the members were welcomed by the mayor of the city; the subsequent meetings were in the convention hall at the hotel. Because of the funeral of President McKinley, which occurred on Thursday, the 19th, the regular program for the sessions on that day was omitted, and no business was transacted.

The following members and guests were registered: —

MEMBERS.

Charles H. Baldwin, Lewis M. Bancroft, Joseph E. Beals, Forrest E. Bisbee, James W. Blackmer, George Bowers, James Burnie, A. H. Burse, George Cassell, Byron I. Cook, F. H. Crandall, George K. Crandall, J. W. Crawford, Allan W. Cuddeback, Eben R. Dyer, August Fels, B. R. Felton, Murray Forbes, Andrew D. Fuller, D. H. Gilderson, T. C. Gleason, Albert S. Glover, Frederick W. Gow, E. H. Gowing, James W. Graham, Frank E.

Hall, George W. Harrington, V. C. Hastings, W. C. Hawley, T. G. Hazard, Jr., Willard Kent, Charles F. Knowlton, Harry A. Lord, Cyrus M. Lunt, A. E. Martin, Frank E. Merrill, William Murdoch, Frank L. Northrop, W. Paulison, Edward L. Peene, F. H. Pitcher, J. B. Putnam, Walter H. Sears, Edward M. Shedd, Charles W. Sherman, M. A. Sinclair, H. T. Sparks, Robert J. Thomas, William H. Thomas, George P. Wescott, John C. Whitney, W. P. Whittemore, C.-E. A. Winslow, George E. Winslow, E. T. Wiswall. — 55.

Honorary Member.

F. W. Shepperd. — 1.

Associates.

Ashton Valve Co., by C. W. Houghton; Builders Iron Foundry, by F. N. Connet; Coffin Valve Co., by H. L. Weston; Garlock Packing Co., by Horace A. Hart; International Steam Pump Co., by George J. Foran; Hersey Mfg. Co., by Albert S. Glover and Francis C. Hersey, Jr.; Henry F. Jenks; Kennedy Valve Mfg. Co., by M. J. Brosman; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; H. Mueller Mfg. Co., by F. B. Mueller; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Rensselaer Mfg. Co., by Fred S. Bates; A. P. Smith Mfg. Co., by W. H. Van Winkle; Sumner & Goodwin Co., by Frank D. Sumner and Frank E. Hall; Sweet & Doyle, by H. L. DeWolfe; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by J. P. K. Otis and Frank L. Northrop; United States Cast Iron Pipe and Foundry Co., by E. T. Stuart; Walworth Mfg. Co., by George E. Pickering; R. D. Wood & Co., by Charles R. Wood; The George Woodman Co., by Wm. B. Durfes. — 23 associates, by 26 representatives.

Guests.

Mrs. George Bowers, Mrs. J. W. Crawford, Miss Ellen M. Weaver, Lowell, Mass.; Mrs. Wm. H. Thomas, Miss Helen A. Thomas, Hingham, Mass.; Mrs. F. N. Connet, Providence, R. I.; Mrs. Edward L. Peene, Mr. and Mrs. Michael Walsh, Yonkers, N. Y.; Mr. and Mrs. Wm. W. Locke, South Framingham, Mass.; E. L. Arundle, M. F. Collins, Lawrence, Mass.; Mrs. George E. Winslow, Waltham, Mass.; Mrs. Willard Kent, Raymond Kent, Narragansett Pier, R. I.; Miss Jessie A. Murdoch, St. John, N. B.; Mrs. George K. Crandall, New London, Conn.; Miss Hattie L. Northrop, M. L. Northrop, Saco, Me.; Miss Cora B. Pike, Boston, Mass.; Charles S. Warde, Staten Island, N. Y.; Hon. Frederic E. Boothby, C. W. Fenn, N. E. B. Merrill, Portland, Me.; Mrs. George J. Foran, Boston, Mass.; Mrs. C. F. Knowlton, Quincy, Mass.; Mr. and Mrs. James P. Bacon, Cambridge, Mass.; Miss Mary K. Gleason, Ware, Mass.; Mrs. W. H. Van Winkle, Newark, N. J.; Mr. and Mrs. Kendall Pollard, Swampscott, Mass.; Mr. George F. West, Portland, Me.; M. O. Leighton, Montclair, N. J.; W. N. Goddard, Henry M. Clark, Boston, Mass.; W. F. Wirsing, Greensburg, Pa.; M. N. Baker, Associate Editor *Engineering News*, New York City; George H. Part-

ridge, *Engineering Record*, New York City; John A. Hennesey, Erie, Pa.; W. W. Trowbridge, Miss J. M. Ham, West Newton, Mass. — 42.

SUMMARY OF ATTENDANCE.

Members	55
Honorary Member	1
Representatives of Associates	26
Guests	42
	124
Names counted twice	4
Total Attendance	120

WEDNESDAY, SEPTEMBER 18.

The Association met in the Council Chamber of the Portland City Hall at 11 A.M., President Crandall in the chair. His Honor Frederick E. Boothby, Mayor of Portland, was presented by the President and spoke as follows: —

Address of Welcome by Mayor Boothby.

Ladies and Gentlemen of the New England Water Works Association: We read and are told of the resources of the South, of the grandeur and the manufactures of the Middle States, of the population and the granaries of the West and Northwest, and of the possibilities of the Pacific Coast, but of late years, especially at this season, attention is more and more being diverted to the old Northeast, and I welcome you to-day to its fairest gem, — Portland-by-the-Sea.

It is fitting that you should come to the State of Maine for your meeting, the State around and within which there is so much water; for, taking the shore line, for instance, while the length of the same in a nearly direct course is less than two hundred and fifty miles, yet with the sinuosities of the shore, of boundary river courses, etc., there are about twenty-five hundred miles of coast. Again, within the borders of the State there are, according to recognized authorities, 1 620 lakes with an aggregate area of 2 300 square miles, which, connected as they are with the river systems, afford storage for the vast quantities of water needed by the 5 151 rivers and streams in the State.

While Maine cannot really be considered a mountainous State, it is distinctively a hilly one, and its valleys thus afford the necessary reservoirs for its vast number of lakes. Many of these lakes are

situated within easy distance of large cities and towns, and are thus convenient for the operation of water works, in which you are so deeply interested. Very few of our cities and towns are obliged to obtain their water supply from rivers, liable to pollution by manufacturing establishments, etc., but most of them are able to obtain from said lakes the purest of water; and right here in Portland we are willing to challenge the world to produce better water than our Sebago; and I am exceedingly glad that on Friday next you are to view Sebago Lake for yourselves, and trust it will be found satisfactory.

As you know, Maine has become a great vacation State, and the city of Portland is during the season filled with visitors, and to my mind it is not only the magnificent scenery of shore, mountain, river, and lake which is to be had in Maine, but its popularity is due to the quality of its drinking-water as well. How much different, then, are we from our Western brethren. At our hotels you can always tell the strangers by their orders for Apollinaris water, they not knowing of the purity of Sebago though of late years I will acknowledge they order Poland as frequently as Apollinaris.

It is somewhat a matter of regret that your meeting here should be held at a date after the amusement season had closed, though all of our resorts are still open, and I trust it is your intention to visit the same and to also view our beautiful city, and shall hope to later hear that your verdict is that we are all right.

Yesterday I had the report of the Board of Registration handed me, and find that our number of polls is 14 307; and while by the last census our population is 50 145, — and you know we never think such a count correct, — yet with the adjoining cities of South Portland and Westbrook, and the towns of Cape Elizabeth, Falmouth, Cumberland, and Yarmouth, the population of "greater Portland," so to speak, exceeds 75 000, or more than one tenth of the entire State.

Our valuation as rendered by the assessors is $46 000 000, and as the full valuation is hardly ever turned in, we have certainly over $50 000 000, or an average of $1 000 for each inhabitant, a fact which few if any cities can equal.

I have examined your program and note the elaborate subjects up for discussion. There is another which is of deep interest to me, although not new. In my frequent trips over the country, I often find absolutely no trace of streams that I used to know, and some from which I used to catch quite large fish; and is this not due to the

demolition of our forests? and is it not a fit subject for your honorable body to consider? Being, as I am, unacquainted with your proceedings, it is possible that you have already treated this subject. Scientists tell us that the shade afforded by trees prevents the sun from parching away the water contained in the ground, and here in Maine our forests, for the greater part, being evergreen, shade the ground at all seasons. We are also told that forests check the movement of the atmosphere, and thus prevent the removal of moisture from their area; and again, that forests roughen and break up the ground through which their roots force passage, so that the water penetrates it. But I do not propose to keep you longer with words on a subject in regard to which you are better informed than I, but cannot help mentioning one which appeals so strongly to me.

Again, then, bidding you a hearty welcome to our city, which is but the gateway to many points of interest beyond, I will close by hoping for a better acquaintance, which shall result in a more frequent interchange of visits, so that a pilgrimage to Portland will be an annual event in your lives. [Applause.]

The President. Mr. Mayor, in behalf of the New England Water Works Association I thank you for your words of welcome. I am reminded, as I stand before you, of an incident which occurred, I believe, in Auburn, in this State, when the president of a Dorcas Society, responding to words of welcome by an eloquent pastor, told the gentlemen that his kindness was only equaled by his extreme good looks. I assure you, Mr. Mayor, that your kindness is appreciated by all the members of the Association, and —

The Mayor. How about the good looks? [Laughter.]

The President. I was going to add that I know that the ladies have all been particularly impressed by those. [Laughter and applause.] As you are perhaps aware, in the constitution of the New England Water Works Association provision is made, lest becoming fixed like a plant in one peculiar spot we should share the common fate of plant life, for the holding of our annual conventions in different localities. With your fair city, its historic associations, its beauty of location and the energy, enterprise, and public spirit of its citizens to inspire us, I feel sure that the success of our present convention is assured. Again thanking you, Mr. Mayor, for your cordial reception, I extend to you, and to any of your fellow-citizens who may be interested in water-works matters, an

equally cordial invitation to attend our meetings and to participate in whatever of profit and pleasure may result from the sessions of our twentieth annual convention. [Applause.]

We will now proceed with the business of the hour.

Mr. George P. Wescott.* I move you, Mr. President, that at the close of our session this evening the convention adjourn, and that we do no business on Thursday, but observe the day in recognition of the funeral at Canton, Ohio, of the late President of the United States, William McKinley.

Mr. August Fels. I think it very appropriate that we, as members of the New England Water Works Association, should thus publicly express our deep sense of the nation's loss, and I therefore second the motion.

The motion was adopted. The Mayor announced that services would be held on Thursday morning in various churches, which he named, and in the afternoon at City Hall, to which he especially invited the members of the Association.

New Members Elected.

The Secretary read the following names of applicants for membership: —

Resident.

Charles W. Fenn, Portland, Me., Manager Mechanics Falls Water Works, Manager and Treasurer North Berwick Water Works, Engineer of Caribou Water and Electric Light Co.

Frank A. McInnes, Dorchester, Mass., Engineering Department, Boston Water Works.

Edwin F. Dwelley, Lynn, Mass., Civil Engineer.

Henry A. Fiske, Newton Center, Mass., Manager, The Underwriters Bureau of New England.

L. R. Woods, Everett, Mass., Superintendent Everett Water Works.

Charles A. Mixer, Rumford Falls, Me., Engineer in charge of design construction and maintenance of works.

Michael F. Collins, Lawrence, Mass., Superintendent of Water Works.

Jerome W. Goodell, Burlington, Vt., Water Commissioner.

Non-Resident.

Joseph C. Beardsley, Cleveland, Ohio, Second Assistant Engineer, Cleveland Water Works.

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* Treasurer, Portland Water Co.

M. N. Baker, Montclair, N. J., Associate Editor *Engineering News*, Consulting Engineer and member Board of Health, Montclair, N. J.

John Goodell, New York, Managing Editor of the *Engineering Record.*

Associate.

J. B. Campbell Brass Works, Erie, Pa.

On motion of Mr. Robert J. Thomas, the Secretary was instructed to cast the ballot of the Association for the applicants, which he did, and they were declared by the President to have been elected members of the Association.

Committee to Nominate Officers.

Mr. C. W. Sherman. In compliance with the provision of the constitution requiring that a committee to nominate candidates for officers for the ensuing year shall be appointed at this convention, in such manner as the convention shall decide, I move that the President appoint a committee of five to bring in a list of nominations of officers for the year 1902.

The motion was adopted and the President appointed as the committee: Messrs. Dexter Brackett, Boston; George A. Stacy, Marlborough; Charles H. Baldwin, Boston; F. F. Forbes, Brookline; J. C. Whitney, Newton.

On motion of Mr. Fels the convention adjourned to 2 P.M.

Afternoon Session.

The President read the following letter from the Portland Company, inviting the members of the Association to visit its works.

Portland, Me., September 18, 1901.

Mr. F. H. Crandall, President New England Water Works Association, Falmouth Hotel, City.

Dear Sir, — We wish to extend to the members of your Association a cordial welcome to Portland, and to state that we should be glad at any time to have any of the members visit our works, and will take pleasure in showing them through.

Our shops include iron and brass foundries, machine shops, boiler, tank, and blacksmith shops, and elevator shop.

We are now building four (4) standpipes for water works, and also some very large pipe for a pumping plant.

While we are not specialists in any line of manufacture, our plant enables us to build a great variety of work in iron and wood.

With best wishes for a successful and enjoyable meeting for your Association, we remain,

Yours very truly,

PORTLAND COMPANY.

Mr. Charles-Edward Amory Winslow read a paper entitled "Bacteriological Analysis of Water and Its Interpretation. — Demonstration of Cultures." The subject was discussed by Mr. George E. Winslow, of Waltham; Mr. W. C. Hawley, of Atlantic City, N. J., and Mr. M. F. Collins, of Lawrence.

UNIFORM STATISTICS.

The next matter on the program was the report of the committee on "Uniform Statistics."

MR. JOHN C. WHITNEY, of Newton, said that the report was in the hands of the chairman, but he had been detained and would not be present until the following day. He suggested that Mr. Sherman, who had been present at the meeting of the committee when the report was prepared, probably had it all in his head and could give it to the Association.

MR. C. W. SHERMAN. I am not authorized, Mr. President, to say anything for the committee. I met with two members of the committee by request last Saturday afternoon, and we discussed possible desirable modifications or simplifications of the present existing summary of statistics, and a possible extension of it to cover filtration or purification works. I have a minute of what we discussed at that time, but I am not authorized to say anything for the committee; so unless the chairman appears with the report before we adjourn we shall have to wait till a later meeting before we hear it.

THE PRESIDENT. Could you not give us some information as to how our own statistics are being accepted by the members, whether they seem to be satisfactory, and whether they are being adopted by an increased number of works, and generally with regard to this matter?

MR. SHERMAN. I shall be very glad, if the members care to hear me, to say a little on the subject of statistics in general, without having it come under the head of the report of this committee. As

some of you know, and more of you will when you get the next JOURNAL, I have been spending part of my spare time this summer in compiling statistics from the water works reports for publication in the next JOURNAL. I made a special attempt to secure reports from all cities and towns containing summaries of statistics in the form adopted by this Association, and I believe I have all such reports which had been published up to the time of going to press with that part of the JOURNAL. I also succeeded in securing manuscript reports on blanks furnished by the Association from eight other municipalities, and found statistics in reasonably accessible form, giving a good deal of the data called for, in twenty other reports, which were accessible to a sufficient extent to pay for compiling the figures. I have brought those figures together in a tabulation which will appear in the September JOURNAL. There are sixty-one municipalities represented in this tabulation, the figures for twenty of which were compiled, as I say, from reports not using our summary or statistics. I have reason to believe that most, if not all the places from which I received manuscript statistics will adopt the summary in their next published reports; and one other city, Reading, Pa., whose printed report has only been received within a week, has adopted the summary this year.

It is proposed by the Executive Committee to print, as we have done this year, although too late for most municipal reports, blank forms of the summary, giving the various items and leaving the figures blank, so that any superintendent who desires to use the summary in his report will have simply to fill in the figures, cross out the headings not applicable to his particular works, and send the sheets thus filled out to the printer as a part of his annual report, and thus almost no labor will be involved in its preparation.

I might also say that Mr. Beals, the chairman of this committee, tells me that he has received a large number of letters from committees of allied associations, having to do with uniform statistics, and from individuals, asking about the progress of water-works statistics, and requesting suggestions, but not one of them offering a suggestion. And I may mention the fact that several water works in what we used to call the Western States, the Western Central States, situated at considerable distances from New England, and in some cases not represented in our membership, have summarized their statistics practically in the form recommended by this Association; and in all probability the slight variations from that form have

been due to the fact that no authentic statement of just what the Association recommends has been obtainable except in an early and comparatively rare volume of our proceedings, and the headings were probably obtained from other reports purporting to use our statistics, but in which, for various reasons, perhaps, they had been slightly varied from time to time, eventually resulting in quite a modification.

Mr. George E. Winslow, of Waltham, Mass., related his "Experiences in Reducing Water Ram Produced by Direct-acting Pumping Engines."

The President announced that an invitation had been received from a member of the Association, Mr. Wescott, to attend a banquet at seven o'clock on Thursday evening, in the dining-room of the New Falmouth Hotel.

Mr. Sherman. As we probably will not have a business session to-morrow or on Friday, it seems to me that this is the proper time to tender to Mr. Wescott the thanks of the Association for his kind invitation; and I therefore move a vote of thanks at this time in order that it may appear in the records of the business meeting.

Adopted.

Evening Session.

The Secretary read the application of Charles S. Warde, Staten Island, N. J., Cashier of the Staten Island Water Company, for non-resident membership. On motion of Mr. Cook, the Secretary was directed to cast the ballot of the Association in favor of Mr. Warde, who was declared elected.

EXHIBIT OF WATER-WORKS APPLIANCES.

Mr. Henry F. Jenks, who had charge of the exhibit of water-works appliances, presented the following report: —

Report on Exhibits.

Meters.

National Meter Co., New York. Represented by J. G. Lufkin and C. H. Baldwin.

Hersey Manufacturing Co., Boston. Represented by F. C. Hersey, Jr., and A. S. Glover.

Union Water Meter Co., Worcester. Represented by J. P. K. Otis and Frank L. Northrop.

Neptune Meter Co., New York. Represented by H. H. Kinsey.

Thomson Meter Co., New York. Represented by S. D. Higley.

Tools and Supplies.

A. P. SMITH MANUFACTURING CO., Newark, N. J. Represented by W. H. Van Winkle.

SUMNER & GOODWIN CO., Boston, and H. MUELLER MFG. CO., Decatur, Ill. Represented by F. D. Sumner, F. E. Hall, and F. B. Mueller.

J. B. CAMPBELL BRASS WORKS, Erie, Pa. Represented by John A. Hennesey.

Valves and Hydrants.

COFFIN VALVE CO., Boston. Represented by H. L. Weston.

RENSSELAER MFG. CO., Troy, N. Y. Represented by Fred S. Bates.

Miscellaneous.

LEAD LINED IRON PIPE CO., Wakefield, Mass. Represented by T. E. Dwyer.

GARLOCK PACKING CO., Boston. Represented by H. A. Hart.

HENRY F. JENKS, Drinking Fountains and Self-closing Faucets. Represented by Mr. Jenks.

F. W. SHEPPERD, New York. Special New England Water Works Edition, "Fire and Water."

Mr. William W. Locke, Sanitary Inspector, Metropolitan Water Works, South Framingham, Mass., read a paper entitled, "The Work of Sanitary Inspection on the Metropolitan Water Works." The subject was discussed by Mr. George E. Winslow, of Waltham, Mass.; Mr. Charles W. Sherman, of Boston; Mr. M. O. Leighton, of Montclair, N. J.; Mr. A. D. Fuller, of Wakefield.

Mr. Charles W. Sherman, in the absence of the members of the Committee on Standard Specifications for Cast-iron Pipe, read the report which had been handed him by Mr. Brackett, of the committee. The subject was discussed by Mr. W. C. Hawley, of Atlantic City, N. J.; Mr. J. C. Whitney, of Newton, Mass., and Mr. Byron I. Cook, of Woonsocket, R. I.

APPORTIONMENT OF CHARGES FOR PRIVATE FIRE PROTECTION AND THE MEANS OF CONTROLLING THE SUPPLY THERETO.

Mr. Byron I. Cook, of Woonsocket, R. I., presented a partial report of the committee on "Apportionment of Charges for Private Fire Protection, and the Means of Controlling the Supply Thereto." Afterwards, on motion of Mr. Cook, the meeting voted to add to the committee, the President (Mr. F. H. Crandall, of Burlington, Vt.) and Mr. Henry A. Fiske, of Boston.

On motion of Mr. Whitney a vote of thanks was extended to Mr.

George J. Foran, for his "work in solving the problem of who is who at this convention" by printing a numbered list of those attending.

Adjourned.

FRIDAY, SEPTEMBER 20.

There was no meeting of the Association, but the party went to Sebago Lake, and by steamer up the lake and the Songo River to the Bay of Naples Inn, where lunch was served; the return to Portland was made over the same route in the afternoon.

OBITUARY NOTES.

John H. Decker, who joined this Association on June 18, 1885, died at his home in Brooklyn, N. Y., on May 8, 1901.

He was born in Allegheny City, Pa., October 10, 1845. He received his education at the Pittsburg High School and the Western University at Pittsburg, but before graduating he enlisted in the One Hundred and Second Pennsylvania Volunteers and served from 1861 to 1863, when he was discharged for disability incurred in the battle of Fredericksburg.

Mr. Decker was well known in the West as a constructor of gas and water plants, and had been engineer and superintendent of the water works at Sioux City, Ia.; Hannibal, Mo.; Salina and Winfield, Kan. He was afterwards with the water-works department of the firm of Henry R. Worthington, and later became assistant water purveyor of the city of Brooklyn, the office being changed to assistant engineer in charge of distribution upon the incorporation of Greater New York. He held this position at the time of his death.

He was one of the founders of the American Water Works Association, and had been its president and secretary, serving in the latter position for nine years.

James Monroe Battles, Superintendent of St. Mary's House for Sailors, East Boston, died at the House on June 8, 1901, after a protracted illness. Mr. Battles was born in New Market, N. H., March 2, 1830; son of Benjamin and Charlotte (Smith) Battles. During his early life, he was connected with the Middlesex Cotton Mills in Lowell, and, after many years of faithful service there, he connected himself with the carpet factory in Roxbury and the Merchant's Woollen Mills at Dedham. He was clerk of the Lowell Water Board for eight years, 1880–88. In 1888 he removed to East Boston, to take up missionary work among the sailors, and through his influence and untiring energy in connection with the Episcopal City Mission, he established that important branch of the mission known as St. Mary's House for Sailors, on Marginal Street, East

Boston, and of St. Mary's Church for Sailors adjoining the House. It is safe to say that since the death of Father Taylor there has been no laborer among the sailors in the port of Boston whose death will be more deeply deplored.

Mr. Battles was a life member of the Historic Genealogical Society of Boston, and was prominently connected with church work in the diocese of Massachusetts. He was married in 1866 to Mary Caroline Eaton. He became a member of the New England Water Works Association on June 21, 1882.

ARNOLD H. SALISBURY, Superintendent of the Lawrence, Mass., Water Works, died very suddenly of heart failure at Greenland, N. H., on July 5, 1901.

Arnold Hunt Salisbury was born in Providence, R. I., in 1833. He received his education in Providence and remained there until he was twenty-one years of age, when he went to Augusta, Ga. He lived in Augusta for a number of years, being engaged in the sash and blind business. He left Augusta to accept a position as overseer in the spooling department of the old Washington Mills in Lawrence, his brother, W. H. Salisbury, being agent at that time. Later he became master mechanic in the same mills. In 1875 Mr. Salisbury became connected with the Lawrence Water Works as foreman. He served in this position until May 26, 1887, when he was made superintendent, which position he held at the time of his death.

In addition to the prominent position which Mr. Salisbury held in the city by reason of his official duties, he was also prominent in business and social circles. He was a member of the firm of C. N. Perkins & Co., manufacturers of fire department supplies. He was elected a member of the New England Water Works Association on January 11, 1888.

Mr. Salisbury leaves a widow, one son, and two daughters.

WILLIAM H. LAING, who joined this Association on June 13, 1889, died at his home in Racine, Wis., on August 5, 1901.

Mr. Laing was born September 18, 1842, at Quincy, Mass. He served during the Civil War in the Twelfth Illinois Cavalry. He was afterwards in the railway mail service, and later became superintendent of mails at Racine. In 1887 he became superintendent of the Racine Water Company, and soon after he was made secretary; and held both positions until his death.

Samuel G. Stoddard, Jr., Superintendent and Engineer of the Bridgeport Hydraulic Co., died at his home in Bridgeport, Conn., on August 21, 1901. He was thirty-four years of age, and left a wife and one child.

He was born in Westville, Conn., and was educated in the Bridgeport schools. After leaving school he entered the employment of Schofield & Starr, engineers, and remained with them until he was made engineer of the Bridgeport Hydraulic Co., and later became superintendent as well. He had entire charge of the construction of the Easton reservoirs, and has been most actively engaged in the building of the Beaver Brook Reservoir in Stratford, and the Uncowa distributing reservoirs in Fairfield, and the introduction of the company's water system to Fairfield and Southport. He was but twenty-four years old when he was appointed engineer of the water company, and only thirty when he became its superintendent.

Mr. Stoddard was elected a member of the New England Water Works Association on June 9, 1892.

NEW ENGLAND WATER WORKS ASSOCIATION.

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THE BACTERIOLOGICAL ANALYSIS OF WATER AND ITS INTERPRETATION.

BY CHARLES-EDWARD AMORY WINSLOW, INSTRUCTOR IN BIOLOGY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

[*Presented September 18, 1901.*]

INTRODUCTION.

The determination of the exact number of bacteria present in water was for a long time a difficult problem, and the greatest advance ever made in bacteriological technique was the method of solid cultures, or rather of cultures either solid or liquid at will, suggested by Robert Koch in 1881, which finally solved this difficulty. If a measured quantity of water be mixed with a portion of melted nutrient gelatine and poured out on a cool glass plate, the medium solidifies and the contained germs are imprisoned and separated from each other. Each bacterium multiplies rapidly by division, producing finally a visible colony; and by counting these colonies the number of individual germs in the original sample may be determined. Very soon after its introduction this method was extensively applied to the sanitary examination of water, and it was at first assumed that the number of bacteria was a rather direct measure of sewage pollution. This too exalted idea of the importance of the bacterial count was followed by a tendency to discredit it altogether, and this, in the present time, by a wiser confidence born of more exact knowledge of the real significance of the test.

Pasteur's work established not only the relation of bacteria to disease, but of specific bacteria to individual diseases. It seemed obvious, therefore, that the best possible evidence of the contamination of water would be the isolation of such specific germs,— in particular of the germ of typhoid fever, the principal water-borne

disease. At first the attempt to isolate these forms appeared to be successful: both the typhoid bacillus and the spirillum of Asiatic cholera were reported as found in many water samples. Further study made the problem much less simple. A large variety of closely allied forms were found in water, resembling both these organisms. Test after test devised to distinguish the disease germs from the related bacteria broke down, and each failure discredited the isolations published by previous investigators. Even in the latest test of all, the Widal reaction with the blood serum of a typhoid patient, it appears that the difference between the typhoid germ and the normal intestinal bacillus is one only in degree and not in kind. The tubercle bacillus, the diphtheria bacillus, and many other forms can be identified with certainty by animal inoculation. Typhoid fever, however, cannot be communicated to the lower animals; and although there is no doubt as to the identity of the germ when isolated from the cadaver of a typhoid patient, its identification in water is still open to grave doubt. The attempt to find specific disease germs in sanitary water analysis has therefore fallen into disrepute.

The closely related forms which proved so great an obstacle in the isolation of the typhoid bacillus have, however, furnished a key to the problem. The commonest of them, the *Bacillus coli communis*, can be identified with comparative ease and certainty. When present in water it indicates, not the presence of infection, but that of fecal pollution. The probability that fecal pollution may imply infection is so strong that this test amply suffices for all practical purposes. During the last ten years the attention of sanitarians has been turned more and more from the direct to the indirect sign of danger, from the typhoid to the colon bacillus, on the theory that the occurrence of the latter implies the presence of sewage, and that any water containing sewage may safely be condemned. On the quantitative analysis, measuring, within certain limits, decomposing organic matter, — and the colon test, indicating more specifically that derived from intestinal discharges, — the bacteriological analysis of water is based.

TECHNIQUE OF QUANTITATIVE ANALYSIS.

The extreme delicacy of the test renders imperative the utmost care in the technique of bacteriological analysis; for a speck of dust, a delay of a few hours, or a mistake in the preparation of the nutrient gelatine, may introduce an error in excess of the normal

difference between the purest and the most polluted drinking-waters. First, in the collection of the sample, it must be certain that the small portion taken represents fairly the whole body of water from which it is drawn. The first water flowing from a tap or a pump must be rejected, as it may have acquired impurities from the mouth of the faucet or of the spout. On the other hand, water which has stood all night in the service pipes of a house will be lower in bacteria than the supply from which it is derived. In a lake or pond the surface scum and bottom sediment must be equally avoided.

In the second place, almost as soon as the sample has been collected, it begins to undergo change. As far back as 1879, Miquel observed that the number of bacteria in a sample of water ran up rapidly if it were allowed to stand before plating.* The light, the temperature, the predatory microörganisms, and other factors less clearly understood, are of more importance in keeping down the bacteria in nature than the lack of food supply; and the disturbance of these relations allows a rapid multiplication. In the purest natural waters, where the numbers are normally smallest, the increase on standing is most startling. Thus the Franklands record the case of a deep well water in which the bacteria increased from 7 to 495 000 in three days.† It is, of course, improbable that in absolutely pure water any such growth would occur, and Miquel found that in condensed water none took place.‡ Even the ordinary distilled water of the laboratory, however, contains sufficient food material to support ample bacterial life. The only sure way to avoid this difficulty is to plate the sample of water to be tested immediately after its collection; and for this end it would often be advisable to make the plates in the field. Plating samples out of doors or in a dusty room is, however, a difficult matter. As a rule, bacteriologists prefer to work in the laboratory, and to retard the development of the germs in transit by packing the samples in ice. This works well, if the delay be not too long, with relatively pure waters. With polluted waters, however, where the germs, and particularly the sewage forms, adapted to a high temperature, are abundant, a decrease occurs on standing, and the use of ice renders it more marked. Jordan found that three samples of river-water, packed in ice for forty-eight hours, fell off from 535 000 to 54 500;

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* Miquel, Manuel pratique d'analyse bactériologique des eaux. Paris, 1891. p. 12.

† Frankland, P. and G., Microörganisms in Water. London, 1894. p. 223.

‡ Miquel, *loc. cit.*, p. 156.

from 112 000 to 50 500. and from 329 000 to 73 500, respectively.* It is thus evident that the bacteriologist must not only see to the collecting of his own samples, but must be intimately acquainted with their history until they reach his laboratory.

The third chance for error in bacteriological analysis is in the plating of the sample itself. The quantity of the water to be mixed with the melted gelatine must be so regulated by dilution that the number of colonies developing on the plate shall not be too small for average results, or so large that the growth of those which develop first will interfere with the slower forms. Less than ten colonies on a plate will probably produce discordant results ; more than two hundred colonies will give numbers a trifle too low on account of antagonism. The thorough shaking of the sample at this point to secure an even distribution of the contained bacteria, and to separate those which may cling together so that a distinct colony may actually be formed from every germ present, is probably the most vital part of the whole process in securing comparable and accurate results.

In the fourth place, the chemical composition of the medium on which the germs are grown affects most fundamentally the results of the analysis. Of the three media in ordinary use for plate cultures, that made from meat juice, peptone, salt, and gelatine gives the highest figures, and that in which agar-agar, the jelly from a Japanese seaweed. is substituted for gelatine, gives the lowest. Glycerine agar, or the agar medium plus glycerine, is intermediate between the other two. The acid or alkaline reaction of the medium, too, was found as early as 1891 to be important, for Reinsch showed, in that year, that the addition of one one-hundredth of a gram of sodium carbonate to a liter of the medium increased sixfold the number of bacteria developing.† G. W. Fuller ‡ and Sedgwick and Prescott,§ working independently, established the fact that an optimum reaction existed for most water bacteria, and that a deviation either way decreased the number of colonies developing. In accordance with this and other similar work, a definite standard method for making bacteriological media was outlined by a committee of the

*Jordan, E. O. Some Observations upon the Bacterial Self-purification of Streams. Journ. Exp. Med., V, 1900, p. 304.

† Reinsch, A. Zur bakteriologischen Untersuchung des Trinkwassers. Centr. f. Bakt., X, 1891, p. 415.

‡ Fuller, G. W. On the Proper Reaction of Nutrient Media for Bacterial Cultivation. Public Health, XX, p. 381.

§ Sedgwick, W. T., and Prescott, S. C. On the Influence of Variations in the Composition of Nutrient Gelatin upon the Development of Water Bacteria. Public Health, XX, p. 450.

American Public Health Association in 1897.* Such a uniform standard is an obvious necessity in order to secure the comparability of the results of various observers. Within limits, it is of no great importance that one method allows the growth of more bacteria than another. At best only a certain proportion of the total germs present in water appear in our artificial cultures. The common water spirilla, for example, and the widely distributed nitrifying organisms, are incapable of development in the gelatine plate. Our counts represent a section through the true bacterial flora, a section fairly representative of the ordinary water bacteria, and thoroughly representative of the quickly-growing, rich-food-loving sewage forms. It is only necessary that the proportion appearing should be the same in each experiment. It has been shown that the salt added to our media diminishes the number of bacterial colonies.† The substitution of certain special albumoses for gelatine would probably increase the numbers developing; Fuller and Johnson have even claimed that simple meat infusion and gelatine gives larger figures than the usual peptone gelatine.‡ Yet these changes will not be made until they can be introduced by a general consent among bacteriologists. Comparability is the one vitally essential factor.

In the fifth place, the investigator may not relax his watchfulness even after his plates are made, for the conditions under which they are kept or "incubated" must be looked to. Development will occur satisfactorily only in the dark; Arloing showed that some of the most resistant of all disease germs, the spores of anthrax, were killed by direct sunlight in two hours under favorable conditions; § and even diffused light hinders the growth of the water bacteria. Moisture must be present, for otherwise, according to Whipple's experiments,|| the surface gelatine forms a hard film in drying which may keep counts twenty-five per cent. below their normal value. According to the same author, the bacteria are so sensitive to

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*Report of a Committee of Bacteriologists to the Committee of the American Public Health Association, on the Pollution of Water Supplies. Public Health, XXIII, p. 56. A new report on the subject was made at the Buffalo meeting of the American Public Health Association in September, 1901, in which the standard methods of procedure were extended and modified to some extent.

† The addition of salt is abandoned according to the new standard procedure of 1901.

‡ Fuller, G. W., and Johnson, G. A. On the Question of Standard Methods for the Determination of the Numbers of Bacteria in Waters. Public Health, XXV, p. 574.

§ Arloing. Influence de la Lumière sur la Végétation et les Propriétés pathogènes du Bacillus anthracis. Compt. Rendus, Vol. 100, 1885, p. 378. Also Vol. 101, pp. 511 and 535.

|| Whipple, G. C. On the Necessity of Cultivating Water Bacteria in an Atmosphere Saturated with Moisture. Technology Quarterly, XII, 1899, p. 276.

changes in the amount of oxygen that the bottom plates in a pile show smaller numbers than the upper ones on account of the exhaustion of this gas by the bacterial growth above.

Finally, the sixth problem for the bacteriologist is to determine the time he shall allow to elapse before the colonies on his plates are counted. The rapidity with which different species develop varies widely. Miquel states * that only seventy-five per cent. of the water bacteria, capable of growth on gelatine, formed visible colonies during the first week, and French bacteriologists still continue to recommend an incubation period of from seven to fifteen days. German official regulations, on the other hand, call for a forty-eight hour period; and in this country counts are usually made on the third or the fourth day. In practical sanitary work there can, I think, be no doubt of the wisdom of adopting an arbitrary short period of time. The practical conditions of the laboratory forbid the storage of large numbers of plates for weeks and months. Furthermore, the sewage bacteria, in which the sanitarian is chiefly interested, develop rapidly. The slowly growing forms have for him but little significance, and to include them in his counts would be useless if not misleading. Here again the ideal of the bacteriologist is to furnish conditions favorable to a large proportion of water bacteria, and to insure the constancy of the conditions in all his experiments.

INTERPRETATION OF QUANTITATIVE ANALYSIS.

The older experimenters attempted to establish arbitrary standards, by which the sanitary quality of a water could be fixed automatically by the number of germs alone. Thus Miquel furnished a table according to which water with less than 10 bacteria per cubic centimeter was "excessively pure," with 10 to 100 bacteria "very pure," with 100 to 1 000 bacteria, "pure," with 1 000 to 10 000 bacteria, "mediocre," with 10 000 to 100 000 bacteria, "impure," and with over 100 000 bacteria, "very impure." † Few sanitarians would care to dispute the appropriateness of the titles applied to waters of the last two classes; but many bacteriologists have placed the standard of "purity" much lower. The limits set by various German observers range, for example, from 50 to 300. Even Dr. Sternberg, in a much more conservative fashion, has stated that a water containing less than 100 bacteria is presum-

* Miquel, *loc. cit.*, p. 33. † Miquel, *loc. cit.*, p. 129.

ably from a deep source and uncontaminated by surface drainage; that one with 500 bacteria is open to suspicion; and that one with over 1 000 bacteria is presumably contaminated by sewage or surface drainage.* This is probably as satisfactory as any arbitrary standard which could be devised, but any such standard must be applied with great caution. The source of the sample is of vital importance in the interpretation of analyses; a bacterial count which would condemn a spring might be quite normal for a river; only figures in excess of those common to unpolluted waters of the same character give the indication of danger. Thus in pure rain water, bacteria, if present at all, range usually only from units to tens. In springs and deep wells it was once believed that sterile water could be found; but Sedgwick and Prescott and others have shown that this is fallacious.† The observers mentioned found sometimes two and three hundred bacteria in unpolluted deep wells and in woodland springs among the hills of New Hampshire; more commonly, however, the bacteria in water of this class will be measured also in units and tens. In lakes the point at which the sample is taken is of great importance, as the bacterial content varies with the distance from shore and with the depth below the surface. Ordinarily the counts will not fall below ten nor rise above five hundred. Finally, the water of rivers, even when unpolluted by sewage, may, at times, contain thousands of bacteria. The season of the year in this case is a controlling factor of importance. As will be seen from the three instances in the subjoined table, the bacterial counts are highest in the winter and spring months, and lower from April to September.

NUMBER OF BACTERIA PER CUBIC CENTIMETER IN CERTAIN SURFACE WATERS.

Water	*Year*	*Observer*	*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*June*
Boston Tap Water	1892–5	Whipple ‡	135	211	102	52	53	86
Merrimac River .	1899	Clark §	4 900	5 900	6 300	2 900	1 900	4 700
Thames River . .	1888	Frankland ‖	92 000	40 000	66 000	13 000	1 900	3 500

* Sternberg, G. M. Manual of Bacteriology. New York, 1892. p. 562.

† Sedgwick, W. T., and Prescott, S. C. On the Bacterial Contents of Certain Ground, Waters, Including Deep Wells. Twenty-Sixth Ann. Rep., State Board of Health of Mass., 1894, p. 435.

‡ Whipple, G. C. Journ. N. E. W. W. Assoc., X, p. 217, June, 1896.

§ Thirty-First Annual Report, State Board of Health of Mass., 1899, p. 486.

‖ Frankland, *loc. cit.*, p. 90.

NUMBER OF BACTERIA PER CUBIC CENTIMETER IN CERTAIN SURFACE WATERS. — *Continued.*

Water	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Boston Tap Water	73	81	86	55	56	52
Merrimac River	3 700	5 000	5 200	9 300	9 800	9 800
Thames River	1 070	3 000	1 740	1 130	11 700	10 600

This spring increase in the content of surface waters is not an exception to the rule that high numbers are dangerous, but an excellent illustration of it. At this season of the year, rivers and small unprotected reservoirs are heavily polluted by melting snow and washings from the surface of the ground, and it is precisely at such times that specific infection of surface supplies and water-borne epidemics of typhoid fever are most likely to occur: witness the disastrous New Haven epidemic of last spring and the regular spring typhoid in Philadelphia and Chicago.

In all these cases it is, of course, not the large numbers of bacteria, in themselves, which are directly harmful. The real source of danger lies only in the comparatively small proportion of disease germs, so small a proportion as to be practically beyond the reach of our method of analysis. But excessive numbers of bacteria, except under peculiar conditions, to be noted later, point, like the free and albuminoid ammonia of the chemist, to the presence of organic matter, and, with much more certainty and delicacy than do those compounds, to the presence of putrifying or recently putrifying organic matter. Such organic matter can scarcely, under practical conditions, gain access to a water supply except from sewage or from fresh surface drainage. In either case the entrance of the specific germs of disease is a possibility, and the water, for safety, should not be delivered to consumers.

It has often been said that single bacterial analyses are valueless; but this, I think, can scarcely be maintained. Knowing the normal bacterial range for a water of a certain class, even an isolated analysis may show such an excess as to have great significance. In the spring of 1900, for example, Mr. Henry Souther and I made a few analyses of the water from the double source of supply used at that time by the city of Hartford, Conn. The first plates we made showed us that the water from the Connecticut River contained from

four thousand to seven thousand bacteria per cubic centimeter, with *Bacillus coli* constantly present, while that from the impounding reservoir normally used by the city contained three hundred to nine hundred bacteria and only rarely was *Bacillus coli* found. Armed with this tangible evidence, Mr. Souther forcibly called the attention of the authorities to the danger from the supplementary river supply, which was at once discontinued. Later it appeared that there were twenty-five deaths from typhoid fever during the four months when the river water was in use, against seventeen in the ten months before, and twenty-five in the twelve months after that period. One more instance from my own recent experience: In the typhoid epidemic at Newport, R. I., a year ago, there was some popular suspicion of the public water supply. The chemical analysis was not quite reassuring; but there were only 334 bacteria present per cubic centimeter and no *Bacillus coli*. The water from a well in the infected district, on the other hand, gave 6 100 bacteria per cubic centimeter, and *Bacillus coli* in abundance.* It was no surprise to find, on a further study of the epidemic, that the well was largely responsible for the trouble and the public supply not at all.

It is of course true that the significance of bacteriological analysis is greatly enhanced by the study of series of results covering long periods of time. Its most important function will, doubtless, always be to aid in the supervision of large city supplies where systematic examination gives normal values, from which any deviation will at once be noted. In Chicago, for instance, daily analyses, both chemical and bacteriological, are made, and warnings based on the results are issued to the public; and the relation between bacterial counts and the prevalence of water-borne disease has been found to be striking. It was stated in the official report of the department for 1896 that "the rise in the water pollution line is followed with almost mathematical accuracy by a rise in the death lines of the acute intestinal diseases and of typhoid fever — the former reaching a maximum usually within a week, the latter within five or six weeks."† The study of the effluent from municipal water filters is closely allied to such regular supervision of unfiltered

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* Winslow, C.-E. A. Typhoid Fever at Newport, R. I., in 1900, and Its Relation to Defective Sanitation. Technology Quarterly, XIV, p. 110.

† Gehrmann, A., and Kennicott, C. L. The City Water Supply. Biennial Report, Department of Health, Chicago, 1895–96, p. 175.

supplies. Here indeed bacteriology furnishes the only possible method of control; breaks in the filtering layer, which could be detected in no other way, are at once made manifest by a rise in the bacterial content of the effluent. In Germany regular bacteriological analyses of raw and filtered water are obligatory, and in this country and in England they are being recognized as indispensable.

Next to such series of analyses, in which the water from the same source is compared at different times, come the elaborate studies made of late years as to the exact distribution of streams of sewage in the bodies of water into which they flow, their disappearance by dilution and their removal by self-purification. The fate of the South Metropolitan sewage in Boston Harbor has been studied in this way at the Institute of Technology, and its course, as it is carried out by the tide, mapped out by its high bacterial content with greater accuracy than could be attained by any other method. Some very remarkable facts have been developed by these studies as to the persistence of separate streams of water in immediate contact with each other. Heider showed that the sewage of Vienna, after its discharge into the Danube River, flowed along the right bank of the stream, preserving its own bacterial characteristics, and not mixing perfectly with the water of the river for a distance of more than twenty-four miles.* And Prof. E. O. Jordan, in studying the self-purification of the sewage discharged from the great Chicago drainage canal, found by bacteriological analyses that the Des Plaines and the Kankakee rivers could both be distinguished, flowing along in the bed of the Illinois, the two streams being in contact, yet each maintaining its own individuality.†

There is, as I have noted above, one exception to the rule that high numbers of bacteria imply the presence of putrifying organic matter. The abnormal increase in samples kept bottled before plating has been described; under certain conditions, not clearly understood, particularly in rather pure ground waters, such a multiplication may occur under natural conditions. In all such cases, however, the prevailing bacteria belong exclusively to one or a very few species of non-sewage organisms. Dr. E. K. Dunham cites a

* Heider, A. Untersuchungen über die Verunreinigungen der Donau durch die Abwässer der Stadt Wien. Das österreichische Sanitätswesen, 1893. Belage zu Nr. 31, 3.

† Jordan, E. O. Some Observations upon the Bacterial Self-purification of Streams. Journ. Exp. Med., V, 1900, p. 272.

very instructive example of this sort.* The mixed water from a series of driven wells gave two bacteria per cubic centimeter, while another well, situated just like the others, contained five thousand, all belonging to a single species common in the air. Such cases as this would be very easily distinguished by a casual examination from the crowded medley of colonies of different species, many of them liquefiers and some characteristic sewage forms, which we get from a polluted water. The general appearance of the plates, then, must be considered in interpreting the results of an analysis.

ISOLATION OF THE TYPHOID BACILLUS.

After what has been said already, it is not necessary to dwell at any length upon the methods suggested for the discovery of the specific organism of typhoid fever. The examination of colonies isolated on plates made directly from the suspected water has not been relied on except by a few observers, on account of the small chance of finding the disease germs in the host of ordinary fecal forms. As a rule some preliminary process of "enrichment" precedes the plating; that is, a portion of the water is kept for a time under conditions which will favor the growth of any typhoid bacilli present while retarding the growth of other forms, the result being a considerable increase in the relative numbers of the former. This is practically effected by mixing the sample with nutrient fluid containing a small percentage of free acid, and by incubating it at the body temperature. Finally, Klein and some other observers have increased the chances of success to a maximum by passing a large quantity of water through a Pasteur filter and examining the mass of bacteria concentrated upon its surface.†

All these precautions are, however, insufficient to secure a satisfactory separation of the typhoid germ. The difficulty with the enrichment process is that the acids and the high temperature, although fatal to many water bacteria, are somewhat less inimical to the colon bacillus, the common sewage form, than to the typhoid bacillus itself. The former have, therefore, a strong tendency to overgrow and kill out the latter. Hankin, of the British Army Medical Corps in India, claims to have obviated the difficulty by the following

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* Dunham, E. K. On the Bacteriological Test of Drinking Water. Medical Record, 1889, p. 367.

† Klein, E. Report on an Epidemic of Enteric Fever in the Borough of Worthing. Twenty-Third Annual Report, Local Gov't Board, 1893-94, Supplement, p. 47.

process.* He adds portions of the water to be tested to tubes containing successively increasing proportions of Parietti solution (four per cent. hydrochloric and five per cent. carbolic acid or phenol). The tubes at the bottom of the series, in which the acid is not too strong, become turbid; and instead of taking the tube with the highest amount of acid in which growth occurs (which would probably contain only *Bacillus coli*). Hankin takes the one just below for the inoculation of a new series. Finally pure cultures are isolated on the agar plate and tested by various sub-cultures.

The positive identification of the typhoid bacillus offers more serious difficulties than its separation, and many of the papers published on the subject are quite valueless because this step has not been carried out with proper caution. In the first place most of the tests relied on are negative in character, and designed to distinguish the typhoid from the colon germ, which latter possesses a number of biochemical powers which the former does not. Any determination based largely on negative characters must be dubious because external conditions may temporarily suppress almost any of the characteristics of an organism. Of the forty or more observers who have claimed to have found the typhoid bacillus in water, all but the most recent are quite discredited on account of the insufficiency of their confirmatory tests. When, however, Widal suggested the testing of the suspected germs by placing them in the blood serum of a typhoid patient, which has the property of causing the germs of the disease to "agglutinate" or clump together and become motionless, it seemed that a great stride had been taken. Relying mainly on this test and more neglectful than ever of the other characteristics of the organism, a new series of typhoid isolations has been published. Two French observers, Remlinger and Schneider, found typhoid bacilli everywhere, in water, in soil, and in the feces of healthy individuals.† A German bacteriologist last year made twenty-eight gelatine plates directly from the water of a suspected cistern, and isolated eleven typhoid cultures from them.‡ Hankin has found the disease germs in abundance in the outer world.§ It now ap-

*Hankin, E. H. On the Detection of the Bacillus Typhi Abdominalis in Water and Other Substances. Centr. f. Bakt., XXVI, 1899, p. 554.

†Remlinger, P., and Schneider, G. Contribution à l'étude du bacille typhique. Ann. de l'Inst. Past., XI, 1897, p. 55.

‡Genersich, W. Typhusepidemie durch Typhusbakterien infiziertes Trinkwasser. Centr. f. Bakt., XXVII, 1900, p. 241.

See Arb. a. d. Kaiserl. Gesundheitsamt, XI, 240; Arch. f. Hyg., XXXVI, 178; and Centr. f. Bakt., XXIX, 329, for other recent isolations.

§Hankin, *loc. cit.*

pears, however, that the colon bacillus also is agglutinated by typhoid serum, although in less dilute solution; and that the test is complicated by many unsuspected sources of error.* The absolute specific character of the reaction thus receives a severe blow; and it becomes evident that the serum test alone, without any elaborate study of other reactions, is not sufficient to establish the identity of the typhoid bacillus.

The main reason for receiving the reports of the observers mentioned above with skepticism is that they prove too much. If typhoid germs were present in such abundance in drinking-water, the human race must long ago have been exterminated, or else have acquired an immunity that would render epidemics impossible. The analyses have usually been made some time after the infection of the supply; but typhoid germs are not supposed to persist in natural waters for any very extensive period. Laboratory experiments have shown that they may live in sterilized water for weeks and even months, but that in normal water, under competition with the ordinary water bacteria, they disappear in a few days or, at the outside, in two or three weeks. Epidemiological experience confirms this conclusion, as the cases of typhoid fever caused by a single infection of a water supply are always grouped rather closely about a certain date. Even at the height of infection, the specific bacteria are relatively few in number. Laws and Andrews failed to find the typhoid bacillus at all in the sewage of London, and isolated only two colonies of the germ from a long series of plates made from the sewage of a hospital containing forty typhoid patients.†

Common sense teaches that these observers and not Remlinger and Hankin must be right. I do not think it too much to say that the isolation of the typhoid germ from water has never yet been satisfactorily proved. A positive result of the search for this germ is, therefore, scarcely to be hoped for. A negative result has no significance; and the complexity of the process renders it quite unfit for practical use.

ISOLATION OF THE COLON BACILLUS.

The colon bacillus or *Bacillus coli communis* was first isolated by Escherich, in 1885, from the feces of a cholera patient, and it was

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*Jatta, M. Experimentelle Untersuchungen über die Agglutination des Typhusbacillus und der Mikroorganismen der Coligruppe. Zeit. f. Hyg., XXXIII, 1900, p. 185.

† Laws and Andrews. Report on the Microörganisms of Sewage. Reports to the London County Council, 1894, No. 216.

later found to be the normal inhabitant of the intestinal tract of man and the higher animals. It was not till about 1894 that the examination of water for this organism began to be widely used as a sanitary test, and it is gratifying to note, as an instance of the keen common sense so characteristic of American science, that it has been principally developed in this country. The work of Dr. Theobald Smith in regulating the details of the study of the fermentative power of the bacillus; of Prof. W. T. Sedgwick, under whose direction Dr. A. P. Matthews introduced the Wurtz lactose-litmus-agar process into America in 1893; of Prof. E. O. Jordan, of H. W. Clark, of G. C. Whipple, of W. R. Copeland, and of E. E. Irons may be especially referred to.

The isolation of the *Bacillus coli communis* includes three main processes, — the enrichment of the water by incubation at the body temperature, the separation of pure cultures by plating, and the testing of these pure cultures by inoculation into various other media in order to see whether they possess all the characters of the typical organism. The first step is to introduce a measured quantity of the water, usually a cubic centimeter or a fraction of a cubic centimeter, into a Smith tube filled with a nutrient solution containing dextrose. After twelve hours at the body temperature, any bacilli of the colon group, or of a number of allied groups, will have multiplied enormously, and decomposed the dextrose, producing gas which collects in the closed arm of the tube. If no gas is formed, colon bacilli are absent, and the test need be pursued no further. As in the case of the typhoid isolation, although to a much less extent, there is a danger in the enrichment process that other forms may overpower and kill out a smaller proportion of colon bacilli. The addition of a small amount of carbolic acid or phenol has been suggested in this case, too, as a remedy; and some observers have, I believe, found it successful.* In my own experience it has not worked well with highly polluted waters, which are the only ones in which a harmful overgrowth is likely to occur. The intruding organisms throve on the phenol, and I obtained a smaller percentage of positive results with it than without. The simplest method appears to be to omit the enrichment process altogether in these highly polluted waters and to proceed at once to the lactose-agar plate. With relatively

* Irons, E. E. Some Observations on Methods for the Detection of B. coli communis in Water. Public Health, XXVI, 1900, p. 310.

pure waters, on the other hand, the preliminary incubation in dextrose broth is always of advantage.

If gas be formed in the Smith tube, it is evident that some organism is present which has the power of fermenting dextrose. The next step is to isolate the germs in pure cultures. A very minute portion of the culture in the Smith tube is added to agar containing lactose or milk sugar and some blue litmus, and plated. Now, *Bacillus coli* ferments lactose as well as dextrose, and produces acid which turns the blue litmus red. Colon bacilli, if present, will therefore produce in twelve hours red colonies on a blue ground, and later will turn the whole plate red. After twenty-four to thirty-six hours, the plate will become blue again as the bacteria proceed to attack the nitrogenous matter present and produce ammonia, which renders the medium alkaline once more. This action on lactose has been used by some bacteriologists under the name of "the Kashida test" (Kashida having suggested its use merely to differentiate the colon from the typhoid bacillus *), as a complete demonstration of the presence of fecal bacteria. It is obvious, however, that it signifies simply the presence of some organism capable of fermenting lactose, and there are plenty of such organisms which do not belong to the colon group.

In order to have any value, the test must be carried much further, and must include the study in detail of pure cultures from the red colonies on the litmus-lactose-agar plate. Several colonies from each plate should always be examined; I have systematically used three in my own work, and have sometimes found one giving positive results while the other two were negative. Just what characters to use in defining the "colon bacillus" is a matter of prime importance. The whole question of species among the bacteria is an extremely complex one. Around each definite species are grouped forms differing from the type in one or two of its characteristics. Dr. W. W. Ford has just published descriptions of forty-eight varieties of bacteria isolated from the human intestine, and differing from each other almost imperceptibly.† These variations are often related to the physical conditions surrounding the organism. Bacilli are commonly found in water which might easily be colon bacilli slightly modified by their unusual environment. The more of these forms which are included,

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* Kashida, K. Differenzierung der Typhusbacillen vom Bacterium coli commune durch die Ammoniakreaktion. Centr. f. Bakt., XXI, 1897, p. 802.

† Ford, W. W. Classification of Intestinal Bacteria. Journ. of Medical Research, VI, p. 211.

the greater will be the number of positive isolations. At present our definitions must be more or less arbitrary; each observer will consider as true colon bacilli those which fulfill his particular set of tests, and will class as pseudo-colon organisms those which do not. If we find, having established such an arbitrary standard, that the colon bacillus, as determined by it, is found in waters known to be polluted, and not, as a rule, in those known to be free from pollution, the sanitarian can afford to ignore the theoretical question of specific values, and make confident use of the practical test. It is of course highly desirable that some standard set of reactions should be commonly adopted by sanitary bacteriologists; I hope some such uniform scheme may soon be drawn up by the Society of American Bacteriologists or by the American Public Health Association. At present the plan in use by the Massachusetts State Board of Health and at the Institute of Technology is most widely prevalent in this country. It involves the use of six simple, definite, positive tests, — the growth in gelatine, lactose agar, dextrose broth, milk, nitrate solution, and peptone solution.

The colon test must always, of course, be to some extent quantitative; that is, the organism is found, or is not found, in a certain definite quantity of water. The usual portion is one cubic centimeter; but often one hundred centimeters or even a liter is "enriched" by incubation with the addition of sugar and phenol, and the Smith tube is inoculated from the enriched solution on the following day. With comparatively pure waters the colon bacillus will sometimes be found by this process when a number of one cubic centimeter samples taken at random from the original water would give negative results. The use of these large samples is, however, of very doubtful value; for the presence of *Bacillus coli* in numbers too small to be detected in one cubic centimeter has little sanitary significance. With more polluted waters the use of large portions is not only unnecessary but harmful, on account of the danger of overgrowth by other forms; in such waters, one cubic centimeter will frequently give a positive, one hundred cubic centimeters a negative, result.

On the other hand, it is highly desirable to know whether the colon bacilli present in one cubic centimeter are numbered in units or thousands. This can easily be determined by testing fractional parts of the cubic centimeter in the usual way. If, for example, hundredths of a cubic centimeter give positive, and thousandths negative results, between one hundred and one thousand of the organisms are

present in the unit quantity. Another quantitative method, suggested, I think, by Copeland,* and in use in some of our best laboratories, consists in the enumeration of the red colonies on lactose-agar plates made from the water direct, with or without the addition of phenol. It is of course impossible to work out all the colonies in detail, and the observer must trust to his eye to distinguish the colon colonies from those of other germs which ferment lactose. Personally, I do not think that this distinction can be trusted ; and the records of the number of colon bacilli in a water carried down to units suggests to me a "false and delusive accuracy." The quantitative estimation by the examination of fractions of a cubic centimeter, on the other hand, is thoroughly scientific, and its results are quite close enough for sanitary purposes.

SIGNIFICANCE OF THE COLON BACILLUS.

The colon test has been received by engineers and practical sanitarians with great satisfaction, and has been applied with confidence to the examination, not only of water, but of shellfish and other articles of food as well. On the other hand, certain European bacteriologists within the last two or three years have denied its value. Poujol found the colon bacillus in the water from supposedly unpolluted deep wells ; † and Weissenfeld declared, less than a year ago, that the "so-called *Bacillus coli* may be isolated from water from any source, good or bad, if only a sufficiently large quantity of the water be used." ‡ The results of these observers are due, however, to two defects in their experiments. In the first place, the tests of the identity of the *Bacillus coli* have been usually quite inadequate, and many forms have therefore been included which are not colon organisms ; in the second place, the use of large volumes of water vitiates any practical conclusion from the researches.

The colon bacillus is not confined to the human being. Dyar and Keith § and Smith ‖ have found it in the intestines of cats, dogs,

*Copeland, W. R. The Use of Carbolic Acid in Isolating the Bacillus coli communis from River Water. Journ. Bost. Soc. Med. Sci., V, p. 381.

† Poujol, G. Sur la présence très fréquente du bacterium coli dans les eaux naturelles. Comptes rendus de la Soc. de Biol., 1897, p. 982.

‡ Weissenfeld, J. Der Befund des Bacterium coli im Wasser und das Thierexperiment sind keine brauchbaren Hülfsmittel für die hygienische Beurtheilung des Wassers. Zeit. f. Hyg., XXXV, 1900, p. 78.

§ Dyar, H. O., and Keith, S. C. Notes on Normal Intestinal Bacilli of the Horse and of Certain Other Domesticated Animals. Technology Quarterly, VI, 1893, p. 256.

‖ Smith, T. Ueber den Nachweis des Bacillus coli communis im Wasser. Centr. f. Bakt., XVIII, p. 494.

swine, cattle, hens, and turkeys. A bird flying over a reservoir or a cloud of dust blown from an adjacent roadway might easily produce sufficient pollution to give positive results when large volumes of water are used, and even in occasional single cubic centimeters. But there is no evidence that the colon bacilli originate anywhere else than in the intestinal tract of the higher vertebrates, the only natural environment in which they can find the high temperature and the rich food supply of peptones and carbohydrates to which they are adapted. As Dr. Smith has said, "They are widely distributed in nature mainly because fecal discharges of human beings and animals are a common thing on the soil." *

When the colon bacillus, as defined by the tests noted above, is found in such abundance as to be isolated in a large proportion of cases from one cubic centimeter of water, it is reasonable proof of the presence of serious pollution. Even Weissenfeld's own results show this. In the presumably good waters which he examined he found his imperfectly defined colon bacillus eight times in one cubic centimeter, and twenty times only when he examined a liter; while in the polluted waters he isolated the organisms twenty-four times from one cubic centimeter and twice from a liter only. During the past winter, I examined fifty-eight samples of water from presumably unpolluted sources, including the supplies of Boston, Brookline, Needham, Taunton, Lynn, and Cambridge, and certain bottled spring waters; in only two cases, one out of nine Boston samples and one out of nine Cambridge samples, was a positive result obtained in one cubic centimeter. In one other Cambridge sample, the colon bacillus was isolated from one hundred cubic centimeters; and in nine other cases forms were found which produced red colonies on lactose agar, but were not colon bacilli. Even in twenty-one samples from stagnant ditches and pools and other sources, probably not receiving sewage, but all more or less foul with decaying organic matter, I found the organism only five times in one cubic centimeter and in three others when one hundred cubic centimeters were examined. In nine of the remaining thirteen instances, pseudo-colon bacilli were present which would have been included by the use of the lactose-agar plate alone. If, on the contrary, fresh sewage be really present even in infinitesimal amount, the test must be positive.

Klein and Houston experimented by diluting sewage with distilled water and testing the mixture; they found that a proportion so small

* Smith, T. Water-borne Diseases. Journ. N. E. W. W. Assoc., X, p. 203.

as to be quite indistinguishable by chemical analysis was readily detected by the colon test.* When the underdrains of the Lawrence city filter were relaid in December, 1898, the sand was disturbed and a small typhoid epidemic resulted; Clark and Gage observed that the colon bacilli in the filter effluent were found in one cubic centimeter in seventy-two per cent. of the samples examined instead of in less than ten per cent., as had previously been the case.†

The experience of all who have practically applied the test has, I think, been the same. In delicacy it surpasses chemical analysis; in constancy and definiteness it excels the quantitative bacterial analysis; as an aid and accessory to both it will find an increasing usefulness in the future.

DISCUSSION.

Mr. George E. Winslow.‡ I understood Mr. Winslow to say in his paper that bacteria are in larger numbers in river-waters than in spring waters or ground waters; and I would like to ask him what would be the result of allowing river-water to mix with a spring or ground water, not in large quantities, but perhaps one or two per cent. of river-water; would it be detrimental to the quality of the spring water?

Mr. C.-E. A. Winslow. The mixture of river-water or any surface water with ground water introduces a small proportion of bacteria directly, and also a considerable amount of food supply which would enable those bacteria, and those already present in the ground water, to multiply. I should say it would undoubtedly have a bad effect in those two ways.

Mr. George E. Winslow. The reason I speak of this is on account of the bad effect which I think has resulted to the water in Waltham, which comes from the ground, from letting in a small amount of river-water, which was claimed to be for the purpose of experiment, to see how much water could be obtained by what they call "filtration," as the amount they will require in the future will possibly be larger than the well can supply. The effect has been to

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* Klein, E., and Houston. Report on the Bacteriological Evidence of Presumably Recent and therefore Dangerous Sewage Pollution of Elsewise Potable Waters. Rep. of Med. Off. of Local Gov't Board, 1897-98, p. 318.

† Clark, H. W., and Gage, S. D. The Significance of the Appearance of B. coli communis in Filtered Water. Journ. Bost. Soc. Med. Sci., IV, 1900, p. 172.

‡ Waltham, Mass.

produce a large amount of life, so much that it made the water taste bad.

I objected very strongly to that water being let in, not only on account of the liability of introducing harmless bacteria, but because of the dangerous bacteria which might be in the river. They claimed they could do it safely, that there would be no trouble ; but I held that it would really be detrimental to the water. But what I wanted to know particularly was whether it was of any advantage to ground water, or whether it was unsafe or detrimental; and then I should also like to know, if you can inform me, whether it increases the amount of vegetable form of life in the ground water.

Mr. C.-E. A. Winslow. The growth conditions for bacteria and for other forms of vegetable life are quite different. The food supply of bacteria consists of organic matter ; that of the green plants consists of mineral matter, — nitrates for example. The river-water would introduce the food supply for the bacteria, but the green plants would find an ideal food supply already in the ground water. That is why the effect on the growth of microscopical organisms, aside from bacteria, has always been so bad when ground water, containing food for the green plants, and river-water, containing spores of the green plants, have been mingled. In Brooklyn, for instance, it has caused very serious trouble. There is only one other thing necessary, and that is light. If the reservoir in which this mixed water is stored is covered, multiplication will not occur, but when you have microscopical organisms, food supply, and light, you are bound to get an enormous multiplication.

Mr. George E. Winslow. I can say from observations that I have made that you are right in that. The water was so disagreeable to the taste, and so disagreeable to use in washing clothes, that I, as an interested citizen, visited the reservoir and pumping station. I found the water was very turbid, — you could n't see down more than a foot and a half in depth through the water, — and that caused me to go to the station to find out whether they were running any river-water in, and I found water running in through a six-inch pipe from the filter. To be sure the pipe was n't running full, because it could n't fill the outlet with the head it had, but it did run, say, from thirty thousand to fifty thousand gallons a day, and I found my suspicions were confirmed. I went to the superintendent and talked with him about it, and he could n't see any objection to it, and quoted the State Board of Health's analysis to back up

what he was doing. I objected to it in my talk with him, on account of the dangers from disease, and I also objected to it on account of its increasing the vegetable forms. He paid but very little attention to me, but I made up my mind that it had got to stop. I interested some of our aldermen, and the result was that it was stopped, and the trouble is now disappearing. I went up there some two weeks after the water was shut off from the river, and I found, instead of its having a greenish look and being so dense, it was turning a brownish color. I concluded that the vegetable forms were decaying and that they would gradually settle and the water become clear. I have n't seen it now for over a week, but I do know that we are getting very much clearer water in the city, and I concluded that the river-water was the principal cause of our trouble. Your statement rather shows the same thing.

Mr. C.-E. A. Winslow. Of course I don't know about this specific case at all, but I do not think the addition of river-water to a ground water supply could be possibly justified, as far as regards the question of green growths, or on sanitary grounds. For a city that has a safe supply, as a ground water presumably is, to add river-water, which is, I think, recognized by all sanitarians now as dangerous, is clearly a mistake.

Mr. W. C. Hawley.* Would that apply to a case of mixing ground water and surface water where the waters are taken directly to the mains and distributed from the distribution system?

Mr. C.-E. A. Winslow. It would not apply to the growth of microscopical organisms but it would apply to the sanitary danger, if it was river-water. I do not think unfiltered river-water is ever safe to drink; but it would not cause the growth of organisms if delivered at once to the consumer.

Mr. J. C. Whitney.† I would like to ask Mr. Winslow what filtering process took place in the case of this river-water he speaks of.

Mr. George E. Winslow. In my talk with Mr. Brown, the superintendent, he claimed that the water coming from the river was practically pure; that is, purified from all germs and from all dirt. I asked him how his filter was constructed. He said the water went through from twelve to twenty-five feet of gravel to get to the filter

* Superintendent of Water Works, Atlantic City, N. J.
† Water Commissioner, Newton, Mass.

gallery, as we call it; but from my observation I should say it went through considerably less than that. The filter is made by putting in a coarse material at the bottom between the gallery and the river, and then filling in with finer material until it is brought to the surface and covered; that allows the water to run through from the river to this gallery, which is about fifty feet long, two and a half feet wide, and seven feet deep. The earth between that and the basin where our pure water is, is practically impervious to the flow of this water from the river; very little runs through there. He said he built the filter last fall, a year ago. I asked him if he took readings to know how much water went in, and he said he had. I asked him if there had been any decrease in the flow of water, the amount which would go through this bank, and he said, "It runs the same now as when first built." I told him I thought his "filter" was a mighty good strainer but a very poor filter.

I found on looking where the water emptied from this six-inch pipe upon the stone work in the basin, before it ran into the water in the basin, a space perhaps two feet long by four inches wide, and at the deepest place there was a deposit of decomposed vegetable matter, about an inch and a half thick. I took some of it up and found it was a nice, rich hard mud, and that showed that there was some dirt coming in with the river-water, and that was one reason I made so strong a claim that the river-water should be cut off, because the filter did n't take all the dirt out of the water, and if there were any disease germs in the river they had a grand chance to get in and mix with our spring water and come to us in the city. The chances for disease from Charles River water I consider very large, because there is a very large amount of boating and a number of pleasure grounds and houses along the river.

Mr. M. F. Collins.* I would like to ask Mr. Winslow a question, although it may be traveling a little outside of the subject he was considering, and that is this: If after cleaning your filter you run for a week or two, and your negative loss of head, we will say, is three feet, and you have a vegetable layer forming on top of your sand, and your head remains about the same, whether that is injurious to the water which is going through the filter or a benefit to the water.

Mr. C.-E. A. Winslow. Do you mean whether a deposit of green growth is harmful or beneficial?

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* Superintendent Lawrence (Mass.) Water Works.

Mr. Collins. Yes, sir.

Mr. C.-E. A. Winslow. It is beneficial, I should say, decidedly, from a sanitary standpoint. Anything which adds to the straining effect is good.

Mr. Collins. Let me ask you another question. Would you clean that bed as long as your negative loss of head is what you would consider within safety, or would you allow the water to run through that vegetable growth, instead of attempting to clean it, if it was vegetable growth and nothing more?

Mr. C.-E. A. Winslow. I should think the limit would be purely an economical one.

Mr. Collins. You would let it run as long as you could get a sufficient supply?

Mr. C.-E. A. Winslow. Let it run as long as it was economical to do so; that would be proper from a sanitary standpoint.

Mr. Collins. That is what I wanted to know. You think it would n't have a tendency to do the water any damage, by allowing that vegetable growth to remain?

Mr. C.-E. A. Winslow. That would depend upon the character of the growth. There are essential oils produced by some organisms which would not be removed by filtration.

Mr. Collins. About two weeks after cleaning our filter in the month of August, we had occasion to draw the water off from the filter. There was a green slimy growth all over it. We left the water off for about two days and that all burnt up. Then we let the water run on again, and the loss of head was about what it was before, and that continued for two weeks. I think we cleaned the filter again on the 28th or 29th of August, and we drew the water off on Labor Day, and there has been quite a growth within the week, but our loss of head is n't any greater than it was two weeks ago. That is the reason I would like to know from you, as a scientist and an expert in this matter, whether it would n't be a benefit to allow this to remain on and help the filtering process; or would you attempt to clean your bed this time of the year as long as you could get water enough through the vegetable growth?

Mr. C.-E. A. Winslow. The green growth could not be of any sanitary disadvantage. It could n't cause disease. It might cause a taste in the water, but your experience ought to have taught you whether it does or not.

Mr. Collins. I don't think it does, and our filter has been run-

ning so well, and we have been getting such a good supply of water through it with this growth on it, that I believed it would be a benefit, and I wanted to know for a certainty, if I could, whether it would have a tendency to give the water a taste. It has n't up to this time, although, just before I came away from Lawrence, one lady called me up and said she thought she detected an odor in the water; but as the bed was cleaned as late as the twenty-eighth day of August, I don't think that can be. I simply wanted to know what your opinion would be on that.

Mr. C.-E. A. Winslow. I could not express an opinion without knowing what the organism is.

Mr. Collins. I should judge it was about the same growth that we always have in summer, although a year ago the growth was so extensive that we had to scrape the bed in ten days.

Mr. C.-E. A. Winslow. I ought to say that what I said with reference to river-water, had reference of course to raw river-water. I cannot judge of the efficiency of filtration in the case Mr. Winslow has spoken of.

THE WORK OF SANITARY INSPECTION ON THE METROPOLITAN WATER WORKS.

BY WILLIAM W. LOCKE, SANITARY INSPECTOR, METROPOLITAN WATER WORKS, SOUTH FRAMINGHAM, MASS.

[*Presented September 18, 1901.*]

The public water supplies of cities and towns are derived either from surface supplies or wells. By surface supplies we mean those whose waters are collected from streams and ponds, and stored either in natural or artificial reservoirs for use as needed. If the amount of water needed is large, either the watershed and storage reservoirs must be large or the rainfall abundant. It is manifestly impossible for most cities and towns to own the watersheds from which their supplies are taken so as to exclude all inhabitants from the same, consequently the aim should be to use a watershed with as sparse a population as possible upon it, that the amount of pollution getting into the supply may be a minimum. As the land along most of our large streams is fertile, it is generally kept in a high state of cultivation and is quite densely populated. At every heavy rain large quantities of organic matter may be washed into the streams.

The object in presenting this paper to this Association is to call attention to the dangers constantly menacing the health and well-being of our cities and towns where surface water works are in operation, through the pollution of the sources of supply by house and barn drainage, and to suggest some of the agencies through which such pollution may be prevented. I need only to call attention to the sad experiences of Lowell and Lawrence, where epidemics of typhoid fever have been repeatedly shown to be caused by a polluted water supply, and to the recent epidemic in New Haven, where it was established that the disease was spread by means of the water supply, to convince you that eternal vigilance and the authority to prevent pollution, by the use of stringent measures if necessary, are essential to the well-being of a community.

Perhaps you are not all familiar with the facts relating to the New Haven epidemic, and it may be proper for me to allude to them

here. I am indebted to Dr. Frank W. Wright, health officer of New Haven, for the following statement: —

In the remote limits of an adjoining town, eight miles from New Haven, there had been during the first three months of the year, at different times, three cases of typhoid. The discharges from the patients were not disinfected, but the father of the family was directed to bury them. During the illness of these patients the ground was frozen solid, and there is every reason to believe that there was no true burial of the feces. The alleged place of burial was on a side hill with a steep inclination to a water course leading directly to Dawson Lake, an important reservoir of the New Haven Water Company.

During all the season there had been an unusual absence of rain. On the 11th of March, 1901, however, there was a precipitation of 2.46 inches in twenty-four hours. This heavy fall had a scouring effect upon the surface, carrying all loose débris into the water courses. The temperature had risen during the previous three days so that the surface of the ground was partly thawed, but the deeper ground was still frozen. Doubtless the greater part, or the whole, of the infected material was washed into Dawson Lake by this rain of March 11. The first notice of a marked increase of typhoid was on April 3, twenty-three days after the heavy rainfall of March 11, or on the expiration of the period of incubation. The number of cases reported increased daily until the maximum was reached on April 9, after which there was a gradual decrease until April 15, when the total number of cases reported had reached three hundred and fifty. The persons afflicted were limited very closely to those who were supplied with water from Dawson Lake. No other source of infection was discovered, although the most diligent inquiry was pursued. Many of the students at Yale College were afflicted, and others remained away after the Easter vacation because of the prevailing conditions. Besides the loss of life and impaired physical vigor of the victims, which cannot be reckoned in dollars and cents, the direct financial loss to the city must have been very great.

The city of Boston, through its water board, early recognized the necessity of adopting a vigorous policy to protect the purity of the water. In 1874 a medical commission, consisting of Drs. Charles W. Swan, Edward S. Wood, and H. P. Bowditch, made a very valuable report upon the sanitary qualities of the Sudbury and some other

river-waters. In 1879 Mr. Desmond FitzGerald, then superintendent of the Western Division, made a detailed report to the board showing the number of cases of contamination, and proceedings were begun in the courts against the offenders. But, owing to the uncertain bearing of the law, not much was accomplished until 1885, when the now classic case of Martin *v.* Gleason was decided by the Supreme Court in favor of the city. This decision may be found in the ninth report of the Boston Water Board, page 76. Mr. Gleason was the proprietor of a hotel in Natick, the discharges from sinks and water-closets being conducted by a pipe directly into Pegan Brook, one of the feeders of Lake Cochituate. This decision showed clearly that the city had the right to protect its water supply against pollution as far as the Cochituate watershed was concerned. Mr. FitzGerald's report of that year described ninety-one cases of pollution in Natick, the most of which had been at least partially remedied at the end of the year. Between 1885 and 1889 there were one hundred and thirty-three cases reported in Natick, from which there was direct pollution into Pegan Brook, one hundred and thirteen of which were dwellings or hotels, thirteen were factories, and seven were stables. Although a sewerage system was put into operation in 1896, and every effort short of carrying the cases into court was made, still, out of these original one hundred and thirty-three cases, six were yet unsatisfactory at the beginning of this year, and twenty-one had been only partially remedied by means of cesspools. I have cited the case of Natick to illustrate what is true everywhere throughout the watersheds of the Metropolitan Water Supply, namely, the practical difficulty in the way of persuading people to take care of their wastes. The proper officers should have authority to order and supervise all changes in drainage, and the power to enforce reasonable rules and regulations for the protection of water supplies.

The drainage area of the Sudbury River and Lake Cochituate supplies embraces about ninety-three square miles, upon which there was a total population, according to the census of 1890, of 39 390, or an average of 424 per square mile. The drainage area of the south branch of the Nashua River above Clinton is about one hundred and eighteen square miles, with a total population in 1895 of about 8 160, or 69 per square mile. Although the population of some of the villages upon the Sudbury and Cochituate watersheds has increased since 1890, that of others has decreased, so that the

average per square mile is probably about the same now as then. On the Nashua there has been a material reduction in the population, owing to the removal of houses and factories from the site of the Wachusett Reservoir.

There are several large towns upon these watersheds, where the population is quite dense over small areas, but outside of these centers of population the country is probably no more thickly settled than in the average New England farming community. In towns where there is a public sewerage system, there ought to be no difficulty in getting all houses along the line of the sewer connected with it. This is especially true in Massachusetts, where Chapter 132 of the Acts of 1890, Section 1, reads as follows: "Every building situated on a public or private street, court or passageway, in which there is a public sewer, shall, when required by the board of health of the city or town in which it stands, be connected by a good and sufficient particular drain with such public sewer." This act puts the burden of compelling connections upon the local boards of health, but their labors may be made much less arduous if the town adopting a sewerage system also puts into its by-laws a clause charging sewer rentals. The officers of the town then become interested to keep the tax rate down, by compelling all owners of houses along the lines of the sewer to become users of the same and to bear their proportion of the cost of construction and maintenance.

I am aware that there are not many towns in New England having the watersheds of their surface water supplies within the town limits, or, if such is the case, having a sewer which can be reached. But, as you know, the supply of the Metropolitan Water and Sewerage Board is procured from watersheds located in several towns, and through the local boards of health, acting under the before-mentioned law, we have been able to remedy many cases of pollution. If, in any case, the local authorities should fail to act, under Chapter 488 of the Acts of 1895 the Metropolitan Water and Sewerage Board may enforce the rules and regulations made by the State Board of Health for the sanitary protection of waters used by the water board for the supply of the Metropolitan District. In brief, these rules are as follows: —

No cesspool, privy, or other place for the reception, deposit, or storage of human excrement, and no urinal or water-closet, not discharging into a sewer, shall be located within fifty feet of high-water mark of any lake, pond, reservoir, stream, ditch, water-course, or other open waters used by

the Metropolitan Water Board as a source or for the conveyance, storage, or distribution of its water supply.

No human excrement shall be deposited or discharged in or into such water supply, or shall be kept in or deposited or discharged in or into any cesspool, privy, or other receptacle situated within two hundred and fifty feet of high-water mark of any such waters unless such cesspool, privy, or other receptacle is so constructed that no portion of its contents can escape or be washed into any such waters.

No human excrement, or compost containing human excrement, or contents of any privy or cesspool or sewer, or other receptacle for the reception or storage of human excrement, shall be deposited or discharged upon or into the ground at any place from which any such excrement, compost, or contents, or particles thereof, may flow or be washed or carried into any such waters.

No house slops, sink waste, water which has been used for washing or cooking, or other polluted water, shall be discharged into any such waters, or into the ground within fifty feet, or upon the ground within two hundred and fifty feet of high-water mark of any such waters.

No garbage, manure, or putrescible matter whatsoever shall be put into any such waters, or shall, except in the cultivation and use of the soil in the ordinary methods of agriculture, be put upon the ground within two hundred and fifty feet of high-water mark of any such waters.

No stable, pigsty, henhouse, barnyard, hogyard, hitching or standing place for horses, cattle, or other animals, or other place where animal manure is deposited or accumulates, shall be located, constructed, or maintained, any part of which is within fifty feet of high-water mark of any such waters; and no stable or other place as above enumerated shall be located, constructed, or maintained within two hundred and fifty feet of high-water mark of any such waters unless suitable and adequate provision is made to prevent any manure or other polluting matter from flowing or being washed into such open waters.

No interment shall, except by permission in writing by the Metropolitan Water Board, be made in any cemetery or other place of burial within fifty feet of high-water mark of any such waters.

No manufacturing refuse or waste products or polluting liquid or other substance of a nature poisonous or injurious either to human beings or animals, or other putrescible organic matter whatsoever, shall be discharged directly into, or at any place from which it may flow or be washed or carried into, any such waters.

No person shall bathe in any such waters.

The penalty for the violation of these rules may be a fine of five hundred dollars or imprisonment, not exceeding one year, in the house of correction, or both such fine and imprisonment.

I have not quoted the rules in full, but enough to show that they specify very clearly the various kinds of pollution, and how each case is to be treated.

These rules and regulations do not apply to the water supplies of the other cities and towns of the State ; but if local authorities have difficulty in preventing the pollution of their supplies, they may appeal to the State Board of Health, which, under Chapter 510 of the Acts of 1897, has the general supervision of, and authority to examine, all the streams and ponds used by any city, town, or water, or ice company as sources of water supply, together with all springs,

streams, and water courses tributary thereto, with reference to their purity, and to make rules, regulations, and orders for the purpose of preventing pollution and securing the sanitary protection of the same.

We have usually succeeded in persuading the owner to remedy any defects in the sanitary arrangement of his premises by simply calling his attention to them and explaining what was required; but sometimes we are met by the assertion that he rents his house, and is not responsible for the actions of his tenant. But the Supreme Court has decided that a landlord is liable for the acts of his tenant in polluting the waters of a brook, which is a natural water-course running through the premises, by discharging sink water therein, if the building leased is adapted and intended to be used in the manner complained of, whether he retains control over the house or not. Where an owner will not yield to moral suasion, the local board of health is appealed to if the case can be classed under the head of a nuisance or is dangerous or detrimental to health. In any case there are laws enough in Massachusetts to cover all cases of pollution of a public water supply. Sometimes it requires courage and possible loss of political position to enforce them.

The work done by the sanitary inspector of the Metropolitan Water Works, during the year 1900, is briefly summed up by the Board in its annual report to the legislature, as follows: —

"The watersheds of the various sources of supply have been constantly inspected by the sanitary inspector and his assistant, in order to insure suitable sanitary conditions, and to prevent contamination of the water from infectious diseases. The larger part of the work has been directed to the Sudbury and Cochituate watersheds, but considerable attention has been devoted by the inspector to the Wachusett watershed, partly in assisting the medical inspector, whose attention has been devoted to the works of construction.

"The number of different premises inspected on the Sudbury and Cochituate watersheds has been 1 041. Many cases of objectionable drainage have been prevented, offensive cesspools have been abandoned, the building of sewer connections or cesspools has been required, manufacturing wastes have been diverted from the supply, and in other ways sources of contamination have been removed, so that a marked improvement has been effected in the sanitary condition of the watersheds.

"Endeavor has been made to enforce the statutes of the Common

wealth and the regulations of the State Board of Health prohibiting bathing in all waters which are used for the purpose of domestic water supply."

DISCUSSION.

THE PRESIDENT. Mr. Locke's paper is now open for discussion.

MR. GEORGE E. WINSLOW.* I would like to ask Mr. Locke one question. I was n't here when he began to read his paper, and so I did not hear it all, but I would like to know if boating, fishing, and picnic parties are allowed on the ponds?

MR. LOCKE. Yes; on Lake Cochituate and some of the natural ponds boating and fishing are allowed.

MR. WINSLOW. Is that at all times, or only at certain seasons of the year?

MR. LOCKE. At all times.

MR. WINSLOW. Is that done promiscuously, that is, at anybody's will, or is it done by license from the commissioners or whoever is in charge?

MR. LOCKE. There are certain regulations which people are supposed to observe, and which police officers are appointed to see are enforced, with regard to boating and fishing and the leaving of remains of lunches or dead fish, which tend to pollute the water; but no restriction is put upon people as to boating and fishing at any time or in any place, provided they are reasonably careful.

MR. C. W. SHERMAN.† I would say, in further explanation of that point, that one reason why so much liberty is allowed on Lake Cochituate is that it is one of the "great ponds" of the State, and the public had had rights of that nature in it long before it was taken for a water supply, and those rights have never been curtailed. In the early days it was not thought necessary to pay much attention to these matters, and it has not been considered feasible since to attempt to stop the general use of the lake for boating and fishing. The artificial reservoirs are not used for boating, and they are used for fishing only under license from the board, except at a few specified places, and then under the conditions mentioned by Mr. Locke.

MR. LOCKE. I am asked what area of surface Lake Cochituate has.

MR. SHERMAN. About seven hundred and seventy-five acres.

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* Waltham, Mass.

† Assistant Engineer, Metropolitan Water Works.

Mr. M. O. Leighton.* The rules read by the author define certain distances from ponds and reservoirs within which certain nuisances are prohibited. Suppose there were nuisances outside of these limits, which was, without doubt, polluting the water, what would be the method of procedure in such cases?

Mr. Locke. We strive to treat each case by itself so far as possible. It is impossible to make a rule which will apply to every case, but if we are positive that the supply is being polluted, we appeal usually to the local board of health. If that is not sufficient to remedy the evil, then we take the case up ourselves under the regulations against the pollution of water supplies. There is a case at the present time which has been decided in favor of the water board, although as yet the remedy has not been applied, where the pollution originated a quarter of a mile away from the stream. In that particular case, at times of large flow of water, the drainage from the houses goes into the water supply and at other times it does not; but so long as during a certain season of the year, in the spring or at a time of large flow, the man pollutes the supply, he has been held to be subject to the proper remedy.

Mr. Sherman. There are one or two points which perhaps might be elaborated a little more fully, and it seems to me that it would be interesting if Mr. Locke would give a little further detail concerning them; for example, in relation to the proof that any particular case would be a pollution of the supply, if it became necessary to take a case to the court. Of course there would then have to be adequate legal proof that the waste from any certain premises reached the water supply, and I think a brief statement of the methods employed in obtaining such proof would be of interest to the members.

Mr. Locke. In cases where the drainage is carried underground by means of pipes, and it is impossible from surface indications to prove conclusively that the drainage comes from a certain house, we usually apply the bluing test. We have some bluing which is especially strong, and this is placed in the sink, or somewhere in the drainage system within the house, in the presence of witnesses, and then water is poured in after it, either from the tap or from the pump, and we watch where we think pollution is likely to come out; and if we get traces of bluing in the water — it is quite a permanent color and is very easily distinguishable even though the quantity be very small — we can be pretty positive where the drainage comes

* Montclair, N. J.

from. Where there are several houses in a row, it is not always easy to tell just where the pollution is coming from, and sometimes it is necessary to put the test on to a number of houses in order to be sure.

Mr. A. D. Fuller.* Are there any regular methods of disposal of sewage prescribed or advised in cases of premises which are located out of the reach of a sewer and yet within the watersheds?

Mr. Locke. No. The best we can do in some cases is to advise cesspools, although we do not advocate cesspools if we can get along without them. But where the soil is gravelly, if the owner will build one cesspool, and then go a little further and build a second one as an overflow from the first, the final effluent will be pretty well purified, and we need not anticipate much danger from it. If the soil is clayey or rocky, the problem is a more difficult one. There are certain large plants, like the Deerfoot Farm in Southboro, and the St. Mark's School, where the drainage is considerable in amount, and in cases of that sort filter beds are built. If gravel is not handy it is brought in, and artificial filter beds built and divided into a number of small areas which are each capable of holding at least one day's flow, and then the sewage is turned from one bed to another. In the case of the Deerfoot Farm there are fifteen beds, and one after another is used until the whole fifteen are covered. In the meantime, the water has filtered away from the first ones, the surface is raked off, and the beds are in condition to take another dose.

Mr. Sherman. It may not be out of place in this connection to call attention to the fact that when the towns of Natick and Westboro and the city of Marlboro, all of which are situated in or partially in the Sudbury and Cochituate watersheds, put in their sewerage systems, they were encouraged by the city of Boston by the payment of a certain sum, which amounted to a fair percentage of the total cost of the works, towards the construction of the systems, on condition that the sewage should be discharged and disposed of at some point outside of the watersheds.

Mr. Leighton. I should like to ask Mr. Locke what is done with the surface drainage from the streets in such a place as Natick.

Mr. Locke. Pegan Brook, which flows through Natick and receives the drainage of the streets, runs down to a settling basin near Lake Cochituate, which is made by building an embankment across the brook, and the water is pumped from this basin upon filter beds,

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*Civil Engineer, Boston, Mass.

constructed by the Boston Water Board and operated by the Metropolitan Water Board; so it is all filtered before it finally goes into Lake Cochituate. In that particular case the street wash is taken care of in good shape. The same system is used also in Marlboro.

Mr. Leighton. Are the systems of sewerage in these towns separate or are they combined?

Mr. Locke. They are separate systems.

EXPERIENCES IN REDUCING WATER RAM CAUSED BY DIRECT-ACTING PUMPING ENGINES.

BY GEORGE E. WINSLOW, WALTHAM, MASS.

[*Presented September 18, 1901.*]

Mr. President and Gentlemen, — I have not prepared a formal paper on this subject, as I have n't had time to write one, so I will give you in a conversational kind of way a little experience I had with water ram ; I don't doubt that many of you have had similar experiences.

In 1872–73 the water works were built in Waltham. The pipe from the pumping station to the reservoir was twelve inches in diameter and 2 700 feet long, and one pump of 1 500 000 gallons daily capacity was put in use. This answered very well for the size of the works. In 1881 another 1 500 000-gallon pump was put in service, and we used the same main ; no other main was laid. In due time the amount of water used in the city was so large that one pump would not supply it, and it was necessary to run the second pump also. The friction in the main was so great under those conditions that the pumps could not be run at full speed ; they could be run at about three-quarters speed, and then at times the water ram would be enough to jar the pumps pretty severely.

In 1891 we laid another pipe, twenty inches in diameter, to the reservoir, with the idea that it would not only take all the water these two pumps would lift, but that when we put in a larger pump it would also act as a force main for that ; and this was found to answer very well.

After the second main was laid, the two pipes were arranged so as to allow the use of either one or both by either of the pumps ; but our engineer was very desirous of having them remain separate, and, as a matter of fact, one pump pumped through the twelve-inch main and the other through the twenty-inch.

The next year we increased our supply, by building a well in our receiving basin, carrying it down some eighteen feet below the bottom of the old basin : the water would then be twenty-seven feet deep in the well when at the average level of the water in the river. The old basin

was connected with the pumping station by a conduit, and in the station was a pump well at the same level as the conduit and the basin outside. Both pumps took from this well, with a direct rise and no turn in the pipe, making a short suction. The water, being about nine feet deep, gave us ordinarily a suction of from fifteen to eighteen feet. The pumps ran satisfactorily under those conditions. But when we came to extend the suction to the new well, which we had to do to pump below the level of the old basin, those pipes were about eighty feet in length. These suction pipes were each twelve inches in diameter. We put in the first one, connected the pump and tried it, and found that we could run only fourteen revolutions a minute on account of the water ram. The engineer thought there were leaks in the suction pipe, but we looked it over carefully and found none.

While making the plans for this suction, I conceived the idea that the pumps would n't act satisfactorily without an air chamber on them, and, as a consequence, I had a T made in one of the sections on which I could put an air chamber, but this was some twenty feet away from the pump, and a very poor place for an air chamber. After trying one pump with no air chamber and getting only fourteen revolutions a minute, with a tight suction pipe, I got a piece of six-inch pipe, three feet long, and put it on to this T. This made a small air chamber. The result was that we could run at twenty-two revolutions a minute; so we found that using a small air chamber helped considerably. I then put on a larger air chamber in the same place, and found we could run at twenty-four revolutions a minute. On the other suction pipe was a twelve-inch Chapman valve with the dome up, within seven or eight feet of the pump, which acted as an air chamber. When we started that pump we could get twenty-four revolutions a minute before it commenced to ram. This showed that it would be an advantage to put the air chamber on the cross drum nearer the pump, where both pump cylinders connected, or to get a place for the air cushion as near the pump as possible; that would probably stop the ram. I finally persuaded our commissioners to allow me to do this, and I got an air chamber of the ordinary size, three feet high and a foot in diameter, and applied it to this drum next to the pump.

In order to see what was occurring, I put a water glass on it, and also a vacuum gage. I also connected this air chamber to the condenser of the pump, with an ordinary one-eighth-inch pipe. At first I put that halfway up the air chamber, and it worked well; I thought it might be better to have more air space, so I put it a little lower; and

finally I got it down to about a foot from the bottom of the air chamber. It worked very well indeed, and the pumps could run thirty revolutions a minute, and not do any damage or ramming. In fact, they ran more smoothly than they had ever run.

The reason for putting this pipe into the air chamber was to exhaust the air which would be given up by the suction, and to keep it from getting into the pump proper. I found by shutting off the pipe from the air chamber to the condenser, and watching the glass, that in forty minutes the water would go down 0.1 of a foot, so that there certainly was air being given up by the water. Under those considerations, when the pump was running normally, the pump might, by change of steam pressure, slow one or two revolutions per minute, the water would rise in this air chamber, more air would be given up so it would come down nearly to the bottom of the chamber; then the steam pressure would come up a little, the pumps would increase their speed to correspond, and the consequence would be that some of the air in the air chamber would pass into the pump, and we would get a bang which was disagreeable. By putting the pipe up on the air chamber, it kept the water up in the chamber, so that, if the pump did speed up a little, it would n't give up air, that is, it would n't let the air get into the pumps. Consequently, the pump ran smoothly at all times.

On the suction pipe close by the pump was a pet cock, with a hole perhaps a tenth of an inch in diameter; when the ram came, water would spurt out of that cock at the end of the stroke so that it would strike the other pump, probably ten feet away, and then air would be drawn in. The air chamber relieved that shock. Then the question arose, What produced this shock and how could it be overcome?

Afterwards I thought, and I think now, that the action of the direct-acting pumping engine is not what it should be, for the very reason that a full head of steam is given to the ordinary direct-acting engine for the full length of its stroke, and the valves are operated by the opposite piston from that which is doing the work. The piston comes nearly to the end of its stroke, and then comes against the steam cushion, which is regulated by the compression valves; and the consequence is that, as the piston moves from one end to the other, it maintains the same speed out to about the point where it begins to compress the steam cushion and then stops in a very short distance, and that produces a very heavy ram. If a man were to let water out of a main pipe at the rate that it is being moved by the

pump, and were to stop it in the short space of time in which the piston is stopped, he would be likely to break something.

I have asked a number of engineers who are running pumps what the consequence would be if they could shut off the steam at the end of the stroke and prevent the piston head from coming against the cushion with so much force, but cut the steam down so that the piston would come to a stop of itself without compressing the steam cushion, — perhaps have no steam cushion at all, but let the water that was being pumped stop the piston; and, in most cases, the answer has been. "If you want to run a direct-acting pumping engine you have got to give steam the whole length of the stroke, and that is all there is to it."

Now, I have found that there is something more than giving steam the whole length of the stroke, and I have experimented to see what would happen if steam were cut off; and I find that an engine can be run without using the steam cushion, by shutting off the steam gradually towards the end of the stroke so that when the piston gets to the desired point there is no steam coming into the cylinder, and the piston stops because there is no force to push it against the water. In other words, let the water which is being forced become the cushion; and, by cutting off steam at the point desired, you have a very smooth stroke, and one which does not produce any ram.

Now I don't say that you want to cut off the steam at one half the stroke or commence to shut it off there. You want to shut it off at the point desired, and correspondingly let steam into the opposite cylinder. That is something which will have to be determined by experiment for each case, on account of the different length of strokes of different pumps. I tried my experiments on a small boiler feed pump, and I will give you a little idea of them.

The pump I used was a $4 \times 2\frac{3}{4} \times 4\frac{1}{2}$ inch, in other words, the water end was $2\frac{3}{4}$ inches in diameter. I arranged it so that it ran very smoothly, pumping out of a barrel and back into the barrel, contracting my discharge so as to get the pressure desired. It was a standard pump, well made, by a company which understands its business, and it does good work. At first the pump pressure varied from seven and one half to eight pounds on every stroke, running against fifty pounds pressure. That was the best I could do with it. I put on my attachment and got it to a point where the variation was less than one half a pound on any stroke. I then tried it in different forms to see if I could make the piston strike the cylinder head. With the old

attachment on, I had no trouble at all in making it strike the head, as you have seen many pumps do on water works when you suddenly open up a main or a hydrant. It compresses the steam cushion, the steam behind is pressing just as hard, and the resistance of the water is reduced, and perhaps the piston strikes the steam cushion hard enough to knock the head out.

In the ordinary pump one piston wholly controls the valves of the other piston, and after it has made a stroke the valve remains open until the piston of the other pump closes it. In this case I arranged so that when the piston approached the end of the stroke it shut off its own steam without regard to the motion of the piston which gave it steam and, as a consequence, it stopped easily.

To show you how that worked, I put the old valve motion upon the pump, and I opened the valve with one hundred and five pounds of steam at the boilers — I cannot say just how much there was at the pump for I did n't put on a gage, but the loss was small — and it ran four hundred and ninety-six strokes a minute, or one hundred and twenty-four revolutions; and within three minutes the pump had jumped about four inches along the bench, and would have gone farther if it had n't been prevented. The plunger went against the heads very hard, and I did n't dare run it any longer for fear I would break the pump. I then put on this experimental valve motion and tried that. I wanted to give it just as good a chance as I did the other to run away if it could, so I put a mark on the bench to see how much the pump moved, turned on a full head of steam, and let it go. I ran it for five minutes; it made five hundred and twenty strokes a minute, or one hundred and thirty revolutions. I arranged my valve motion so as to cut off the steam before the piston got to the steam cushion. It ran very smoothly, and during the whole time it made no more noise than under ordinary conditions, and there was no jar whatever. It did n't move enough on the bench so that I could measure it. It was running considerably faster than with the old motion, and running as quietly as at the ordinary fifty strokes, while just before, with the old valve gear, it had been threshing itself to pieces.

I found also that I could take the suction out of the water, with a full head of steam on, and let it run away, and, even under those conditions, the plunger would not strike the heads, but the stroke would be a little shorter. That is something most people do not credit until they see it.

I then concluded that here was something which would be of value for people to know; not perhaps that my device will ever be used, but I do rather think the idea will be used, because it not only insures safety, but I think it is also economical; for when the stroke is completed the steam is shut off, the ram is prevented, and there is no danger of the piston running against the head and knocking it out. It shuts off the steam at the end of the stroke, and if the piston goes at all beyond the point desired it opens up its own valve, from the other side, discharging the steam which is pushing it, and giving steam from the boiler to overcome the momentum of the piston.

It is something I would like to have anybody see who is interested in it. I am not in a position to build any of them; I have n't got the shop or the money to do it with, but I wanted to speak of it on account of its stopping the ram. And another thing: I think the speed of an ordinary pump, running at thirty-five or forty revolutions a minute, can be increased to fifty revolutions. In other words, you can get a larger amount of water out of the same pump by running faster, with perfect safety. You are going to save a portion of the steam which is used to push the plunger against a heavy pressure, and you are going to get an increased duty out of the pump in other ways, and this is in addition to the safety feature of it. Some members of the Association have seen it, and a great many other men who are not present. As I have said, I have no written paper on the subject, and perhaps I have not given as many details in regard to the matter as I should if I had had time to prepare a paper.

DISCUSSION.

Mr. F. N. Connet.* If I understood Mr. Winslow's description, his device is intended to allow a direct-acting duplex pump to work in this manner: The inlet valve for the right-hand cylinder shall be opened by the left-hand cylinder, and the steam shall be cut off by the movement of the right-hand cylinder, and *vice versa*. If that is the device, I would say that the same thing has been exhibited by the Worthington pump people in Brooklyn. Some three or four years ago I saw some new vertical pumps in the Ridgeway pumping station, in which exactly that device was used, and I think the reason for using it was to accomplish the same ends that Mr. Winslow has described.

Mr. Winslow. I will allow that the gentleman is partly correct in what he says, but not wholly. After doing what I did in the mat-

* Engineer, Builders' Iron Foundry.

ter, I thought I would protect myself, so I applied for letters patent and obtained them. In doing so I found I had run against not only Worthington but Gaskill and a man named Clark, in Northampton, but none of them has the same device. In each of those, not only the Worthington but the Gaskill and the Clark, the right-hand valve, which gives steam to the right-hand cylinder, is opened by the left-hand piston, and, when it gets to the end of the stroke, it is closed in part by the action of its own piston and in part by the action of the opposite piston; and on that account there is a failure to accomplish the object I have been after. What I wanted to do was to get a stroke that was always of the same length. Now, in the Worthington, the Gaskill, and the Clark devices, each valve is operated by the action of both pistons, and the consequence is you get a variable length of stroke, and you cannot depend upon it, but you have to use a steam cushion as before. With my device, the right-hand piston opens the valve giving steam to the left-hand piston, and in making its stroke the latter disconnects the valve from the right-hand piston so that, when it gets to the part of the stroke desired, it shuts off the steam independently of the motion of the piston that gave the steam, and *vice versa*. Cutting off the steam independently of the piston that gave it is something that the others do not do. A representative of the International Steam Pump Company called, the other day, and he saw that the device did what I told him it would do. I told him that the longest stroke that the piston would make would be at the time it was doing the most work, that is, when working against the heaviest pressure of water. Now, if the pressure is released by opening a hydrant, breaking a main, or by any other accidental or natural cause, instead of increasing the length of the stroke it shortens it a trifle. In the other devices the stroke could not shorten, but it would lengthen the same as in the ordinary direct-acting pump and possibly do damage.

I would say in addition, although I don't know but I have said it already, that the hardest test I put it to was to unscrew the suction and open up the discharge, and let on a full head of steam and let it run. It ran over twelve hundred strokes a minute, and the stroke was not so long under those conditions as it was in the ordinary operation of the pump. That is something this representative of whom I spoke was a little surprised at, because when I told him sometime ago it would do that, he replied, "If it will, it will do something different from any pump I ever saw."

THE POLLUTION OF STREAMS BY MANUFACTURAL WASTES, AND METHODS OF PREVENTION.

BY H. W. CLARK, CHEMIST, STATE BOARD OF HEALTH OF MASSACHUSETTS.

[*Read November 13, 1901.*]

The question of the pollution of streams and the purification of sewage and manufactural wastes early received the attention of the State Board of Health. After the establishment of the board in 1870, mention of these matters was made in each report, and there is included in the annual report for 1876, a special report upon this subject, as a result of an investigation ordered by the legislature of 1875. This report covers four hundred pages, and it is divided into four parts. The first, upon the pollution of rivers, is a report of an investigation carried on by that noted engineer, James P. Kirkwood, and one of the sub-reports upon the disposal of sewage is by Charles F. Folsom, M.D., at that time secretary of the board, who traveled extensively abroad to collect the data there given. Mr. Kirkwood's report is a general review of the nature of the polluting liquors from various industrial works and cities and towns, together with a statement in regard to the condition of several of the watersheds of the state. In his summary he states that,

"the law under which the investigation was carried on requires the Board of Health to devise a system by which such rivers, estuaries, and ponds may be protected against pollution so far as possible, with a view to the preservation of health of the inhabitants of this commonwealth."

But he adds,

"that to devise and perfect a system as varied in its modes of action as the fluid impurities emanating from the different kinds of works and from ordinary sewage will require, must, as has been hinted above, be a work of time; and while authority must be lodged somewhere to begin this work, it seems obvious that the authority given should, in fairness to cities and manufactories, be exercised at first only conditionally, and that in the case of any fluid impurities requiring to be stopped from entering the stream and to have their poisonous qualities destroyed and the residue rendered innocuous before being passed into the stream, the authority having the power to require this course should be required to show how it can be done and the apparatus and material required to effect it."

At the time this report was written, although forty-eight cities and towns of the state, with an aggregate population of nine hundred and

seventy thousand people, had introduced partial or complete water supplies, only twenty-four had provided even partially for the proper removal by sewers of such large quantities of water as this implied. It is apparent, moreover, to any one who reads Mr. Kirkwood's report that to him at that time the main question in regard to the prevention of the pollution of streams was how to prevent the wastes from large manufacturing establishments scattered all over the state from entering the streams except after, at least, partial purification. In the period of twelve years, however, elapsing between the time of writing that report and the time of establishing the Lawrence experiment station, the number of cities and towns which were sewered increased rapidly, so that, when the board began to study the question of sewage purification in a systematic way at the station, established for that purpose as the result of an act of the legislature, its first investigations were directed almost entirely to the disposal of domestic sewage. From January, 1888, when the work of the board along this line was begun, up to the close of 1894, a period of seven years, the disposal or purification of manufactural wastes was hardly mentioned in its reports, and the disposal and purification of these wastes really seemed at that time of minor importance, not because their careful and scientific purification is not desirable, and is not eventually necessary if the dwellers along many of our streams and rivers are to live in health and comfort, but because the first — the disposal of domestic sewage — is the larger question in which all members of many communities are directly interested and for which they are all in a sense directly responsible.

Beginning in 1895, however, and continuing almost uninterruptedly to the present time, a succession of interesting and practical investigations upon methods of purifying manufactural wastes have been carried on by us, and the results of these investigations have been given partially in the various annual reports of the board and, also, in at least two special reports upon investigations in regard to the pollution of two of the rivers of the state. To those who have studied the rivers and small streams within our state, it is evident that there is a number of the smaller rivers, such as the Neponset, the Sudbury, the Assabet, the Nashua, the French, the Hoosick, Crane's River, and others, which are at places, or along practically their entire course, foully polluted by waste liquors from various manufacturing plants. Some of the large rivers, such as the Merrimac, moreover, are receiving immense quantities of manufactural

wastes, together with domestic sewage, and their waters are prevented only by reason of their volume from becoming as foul in appearance and character as the waters in some of the smaller streams. It is the natural result of the development of the water power of the state, and it is equally as natural that, sooner or later, the people of the state will demand such a cleaning up of the rivers now polluted from these wastes as can reasonably be required or demanded of the corporations or individuals responsible. It is also apparent to one who has looked over these rivers that the principal manufactural pollutions are from woolen mills, paper mills, and tanneries. Other industries cause much pollution in places, but they are not so widespread.

If we take the Neponset River, for example, we find that the manufactural wastes entering its upper portion are largely from paper mills. As it passes through Norwood it receives the wastes from large tanneries, and as it emerges from the Fowl Meadows, at Hyde Park, it receives there and at other places farther along its course the wastes from woolen mills and paper mills. The principal manufactural wastes entering the north branch of the Nashua River are from paper mills and woolen mills; the principal manufactural pollutions entering the French River are from woolen mills; the principal manufactural pollutions entering the Assabet and Sudbury rivers are from woolen mills; and those small streams, Crane's River and the North River at Danvers and Salem, receive the waste liquors from many tanneries. It was natural, therefore, that our first investigations upon the purification or utilization of the wastes from industrial works should be confined to the liquors running to waste from these three industries.

WASTES FROM WOOLEN MILLS.

The principal waste liquors from woolen mills that enter into this subject are those caused by the scouring and rinsing of wool in preparation for its manufacture, together with the waste liquor, in some instances, from washing the cloth after manufacture. They are, perhaps, considering their volume in some places and their composition, the most serious mill pollution in the state. This is so both on account of the large amount of organic matter present in them and the extreme difficulty with which this matter is decomposed or changed by bacterial action. Beginning in 1895, the wastes from quite a number of woolen mills have since been studied by us, and

the results given generally in our regular reports, but occasionally in special reports.

It is not an uncommon thing for wool to shrink sixty or seventy per cent. in weight during the scouring and washing process, and this dirt, fat, etc., removed, together with the soap or other chemicals used in the process, give an extremely dense waste liquor. Domestic sewage contains ordinarily from 50 to 150 parts of solid matter per 100 000 parts, or approximately from 50 to 150 pounds of solid matter in each 12 000 gallons of sewage. The solids in the wool liquors that we have examined, however, average about 2 500 parts per 100 000, that is, the liquors have 2 500 pounds of solid matter in each 12 000 gallons of liquid. In some investigations that I made concerning the character and nature of wool-scouring liquors running to waste from certain mills, I found that one mill, discharging about 67 000 gallons of the liquor per day, discharged about 12 000 pounds per day of solid matter. In a second mill, where the scouring was more concentrated, — that is, carried on with a less volume of water, — the solid matter discharged amounted to 7 500 pounds for each 12 000 gallons of wool liquor. These are not selected cases, moreover, but fairly good illustrations of the character, in this respect, of the wool-scouring liquors discharged from many of our woolen mills.

We found early in this class of investigations, during 1895–1896, that it was impossible to cause this liquor to nitrify when passing through intermittent sand filters, unless a certain volume of domestic sewage was added to it; but we found that, if the volume of domestic sewage was very large in comparison with the volume of waste liquor, nitrification would occur and good results be obtained. As an illustration of this work, I can say that in September, 1898, two filters in operation at the Lawrence experiment station, to which we had applied for some years a mixture of waste liquors from Lawrence wool-washing establishments and domestic sewage, were put into operation, receiving a mixture of domestic sewage and the waste from the wool scouring carried on at the Bigelow Carpet Works at Clinton. This investigation was begun because it was evident that this particular waste liquor would have to be disposed of upon the Clinton sewage filtration area, at that time being constructed by the Metropolitan Water Board. These two filters were continued in operation a year and a half, receiving this waste, and were both constructed of sand of an effective size, similar to much of that in the

area to be used, the proportion of the mixture in the beginning of the operation being one part wool liquor to seventeen parts sewage. Early in 1899 this proportion was changed to one part wool liquor to about eleven parts sewage. The average analysis of many samples of this waste liquor gave about the following results: —

(Parts per 100 000.)

Ammonia.		Oxygen Consumed.	Bacteria per c. c.
Free.	Albuminoid.		
6.20	6.62	79.00	3 000 000

This waste, moreover, besides containing the large amount of organic matter and fats, etc., shown by the determinations of albuminoid ammonia and oxygen consumed, contained a very large amount of fine dirt and sand washed from the wool, this, of course, settling quite easily. This sediment, on analysis, was shown to contain at different times from sixty to ninety per cent. of a very fine sand, and the remainder, or from ten to forty per cent., was organic matter. The two filters were kept in operation a year and a half, and during all that time the mixture was applied directly to one, but before being applied to the other it was first passed through a small septic tank. Good purification results were obtained, the nitrates being high in the effluent of each and the unoxidized organic matter comparatively small in amount; but the filter receiving the mixture which had first passed through the septic tank undoubtedly gave the better results and was freer from clogging at the end of the experiment.

Early last year the board was ordered to make a special investigation in regard to "the sanitary condition of the beds, shores, waters, etc., of the Sudbury and Concord rivers," and "to ascertain whether any danger to the public health exists in said rivers or meadows by reason of stagnant water or of refuse from factories or from other causes; and, if they find that such dangers exist, they shall report to the next general court some plan for its removal." The general results of that investigation are found in House Document No. 1 380 of the last legislature, in which is a report upon an investigation that was made in regard to the disposal of manufactural wastes from mills at Saxonville, these being woolen mills and passing their waste liquors directly into the Sudbury River at that point.

We found from measurements of the liquors run to waste from these mills that about seventy per cent. of the volume was from the processes of scouring and rinsing wool, and that about twenty-three per cent. was waste dye liquor. Many experiments were made with this, as with other wool-scouring liquors in previous years, as to the effect of chemicals in coagulating and removing the organic matter present, but, as in previous years, with quite unsatisfactory results. In all, ten different precipitants were experimented with, either alone or in combination, and we found that an enormous amount of precipitant was needed to cause any coagulation whatever. The failure of these precipitants to cause satisfactory coagulation or precipitation was due to a number of reasons. Of course, as the amount of organic matter present in this waste wool liquor is always much greater than that in ordinary sewage, volume for volume, we should expect to be obliged to use much larger amounts of precipitants. Besides this reason, however, much of the fatty matter in the wool liquor is in a state of semi-emulsion as it runs from the drains in the mills, and is of a specific gravity less than that of water, and any coagulation tends to gather much of this matter in masses that contain a smaller percentage of water than before coagulation. This coagulum, therefore, has considerable buoyancy, and tends to carry some of the precipitants to the surface instead of the precipitants carrying the organic matter down, and this buoyancy is only overcome by an enormous amount of precipitants.

It may be mentioned in passing that in Bradford, England, the center of the English woolen trade, where it is calculated that eight per cent. of the sewage of the city comes from wool-washing establishments, it has been shown by experiment that from nine to twelve times as much precipitant is needed when treating week-day sewage as when treating Sunday sewage free from this waste.

As a result of these experiments, the board advised what it has advised in other cases, that the waste liquors from these mills should be mixed with the domestic sewage of the town and disposed of upon the town filtration area. In this connection it is interesting, and, I think, apparent to any one who has visited the Clinton disposal area from time to time and carefully watched the results of filtration there obtained, that the area seems to gather power to more efficiently purify this liquor after it has been applied to it for some time; that is, the bacteria present in the area seem to become, after a time, more and more equal to the task of breaking up even the stable

organic matters in wool liquor and causing them to undergo bacterial oxidation.

I understand from good authority that in England at the presen time, after long-continued struggles with waste wool-scouring liquor at their town and city precipitation and disposal works, those in charge of these works are now taking the ground that this liquor should not be considered as sewage in any sense and allowed to enter the sewers, until the manufacturers themselves have removed from it a very large proportion of the fat and dirt. Collecting this liquid in stone-lined pits, treating with acid, and collecting and selling the fats saved has long been carried on by certain English French, and Belgian manufacturers, presumably with profit. In America there are a few mills where this has been tried, but not with altogether successful results. Other and more scientific methods of saving the fats and carbonates now going to waste are now being tried in many places abroad, but progress along this line in this country is made but slowly.

TANNERY WASTES.

When, in 1895, the legislature ordered the State Board of Health to investigate the condition of the Neponset River and make recommendations in regard to improving it, we began to study the purification of the waste liquors from the tanneries along this river, engaged in tanning sheepskins, filters being put in operation both at the tanneries and at the experiment station. As a result of these studies it was found that there was no difficulty whatever in purifying this tannery waste by intermittent sand filtration. The sewage of tanneries, as many of you have noted, is a very strong, offensive liquor, highly charged with decaying animal tissues, the bran that is added to cause fermentation to take place in certain tanks, and various chemicals used in preparing, tanning, and preserving the hides. It is also at times highly colored by the different dyes used in coloring the hides, and the spent tan liquor. In spite of this general mixture, however, of organic matter, chemicals, etc., the filters operated by us along the Neponset and at the experiment station for two or three years, beginning in the fall of 1895, showed exceedingly good results. One sand filter, containing four feet in depth of sand, to which this tannery sewage was applied at rates of from 30 000 to 120 000 gallons per acre daily, gave a fairly clear, almost odorless

liquid, without much color and well nitrified; during several months of its period of operation the nitrates reaching 8.00, 10.00, and even 12.00 parts per 100 000.

In 1896, experiments were begun upon the purification of the sewage of a tannery in another portion of the state, engaged in preparing and tanning calfskins. These skins were largely imported, and, to prevent decomposition in transit, were packed in a germicide which was present in the sewage throughout the period of experiment. To aid in the process of freeing the skins of hair at this tannery, a ton or more of sulphide of arsenic was used each month, mixed with lime to form a soluble salt of arsenic, and, as a result, the waste liquor flowing from the tannery always contained arsenic in suspension and in solution. Various other chemicals and dyes were used in the tannery, these dyes being generally bright scarlets and crimsons, used in coloring leather to be made up into the so-called wine-colored shoes. Owing to the germicides used, the sewage as it flowed from the tannery was often sterile, and when not sterile the number of bacteria was very small. A considerable portion of the arsenic was held by the organic matter in suspension, however, and was carried down with this matter when the sewage was allowed to stand for sedimentation to take place, enough often being left in solution, however, to impede bacterial growth. It may be mentioned here, to show the volume of waste liquors from manufacturing plants, that the volume from this single tannery, measured upon several different days, showed an average of two hundred thousand gallons flow in ten hours, and by analysis it was proved to contain twice as much nitrogenous organic matter as is generally present in ordinary domestic sewage, and many times as much carbonaceous matter. By experiments, however, it was found that, although this sewage would not nitrify in filters if applied directly, yet if it was first passed through a coke breeze strainer or over iron filings, the arsenic present in it would unite with the iron, and the resulting liquor would be of such a character that it could be easily purified upon intermittent sand filters. A sand filter four and one-half feet in depth was operated for some months at the rate of one hundred thousand gallons per acre daily, and produced an effluent containing large amounts of nitrates and low in organic matters. It was especially noticeable that the sewage, although often nearly sterile before passing to the small preliminary strainer or filter of coke or iron, showed abundant bacterial growth when it

appeared as an effluent from this strainer before passing to the sand filter.

In continuation of our studies of tannery sewage, we last year operated filters with the waste liquors from a tannery where much wool scouring is carried on, and where this liquor, already described, is mixed with the other liquors from the tannery. In this case, as was expected, the mixture was easily acted upon by the bacteria in the sand filters used, the easily decomposable tannery liquors entirely overcoming the stable organic pollutions in the wool liquor, and good nitrification and purification occurred.

WASTES FROM PAPER MILLS.

The waste liquors from paper mills vary very greatly in character and volume, according to the particular class of work done. Speaking generally, they contain a large amount of slowly decomposable organic matter, such as cellulose, and a small amount of easily decomposable nitrogenous organic matter. They are only difficult to handle because of their volume, and when mixed with fair volumes of domestic sewage are easily purified. In investigations that we have made, however, with these wastes from a number of mills, it has been found that generally, if collected and passed through a coke or cinder strainer, even at rates as great as one million gallons or more per acre daily, the resultant effluent is of fairly good quality, and the polluting matters in the liquors, being largely in suspension, are caught at the surface of the strainer, and form an easily removed felt-like mat, which may be disposed of by burning.

WASTES FROM SILK MILLS.

During the present year I have had an opportunity to study and experiment upon the disposal or purification of the waste liquors flowing from a silk mill. The volume of sewage or waste liquor flowing from this mill daily approximates 2 500 000 gallons, and this liquor varies in character very much during different periods of the day on account of the varying processes carried on in the mill, at one time resembling in appearance domestic sewage and then quickly changing to a bright blue, pink, crimson, or other color, due to the discharge of waste dye liquors; these dye liquors coloring the sewage to such an extent that it is, at times, nearly as highly colored as the dyes in the dye vats.

Besides this coloring matter, a very large and varied assortment of chemicals, etc., is used daily in the mill, a list too long to be enumerated here; but, for an example of the kind and quantity, I will name a few, and the average daily amount of each used.

	Pounds.
Carbonate of soda	124
Silicate of soda	147
Ammonia	52
Sulphuric acid	173
Acetic acid	181
Nitrate of iron	339
Bichloride of tin	237
Sulphate of alumina	60
Sodium phosphate	235
Glauber's salt	88
Chloride of lime	186
Logwood	80
Dextrine	1 307
Vegetable gum	91
Aniline dyes	156
Soap	2 000
Muriatic acid	115
Silk gum, etc., worked off the raw silk and entering the sewage	1 520

The list prepared by the mill people showed approximately fifty different substances.

It was found upon experiment that the surfaces of sand filters became quite quickly clogged when this liquor was applied to them, and it was also found that the chief clogging was caused by the starch, dextrine, soap, silk gum, etc., in the sewage. Experiments were therefore made to determine methods of preliminary treatment of the sewage before application to the sand filters, and three methods were tried; namely, a septic tank, a coke strainer, and a contact filter. After a preliminary experiment, which showed that the clogging matters could be removed by each of these processes, good-sized experimental tanks and filters were put in operation at the mill.

The septic tank and accompanying sand filter were of such size and capacity that the sewage applied to the septic tank was twenty-four hours in passing through, and the rate of filtration of the sand filter receiving this sewage was 200 000 gallons per acre daily. The coke strainer was operated at first at the rate of 1 200 000 gallons

per acre daily, and the contact filter at the rate of 1 350 000 gallons per acre daily, these rates afterwards being nearly doubled. The rates upon the sand filters receiving the sewage from the coke strainer and from the contact filter varied from 150 000 to 225 000 gallons per acre daily.

As a result of these experiments it was found that the coke strainer was the most efficient in removing the clogging matters of the silk liquor, that is, it removed nearly 75 per cent. of these matters; the septic tank removed 50 per cent., and the contact filter about 40 per cent. In each case the resulting liquor, when applied to sand filters at the rate stated, was in good condition for purification by sand filtration, active nitrification in the filters ensuing, and their effluents in each instance being generally quite low in color, notwithstanding the bright colors at times of the sewage applied. Notwithstanding the large and varied amount of chemicals allowed to run to waste from the silk mill, the sewage was never sterile, but contained generally upwards of 3 000 000 bacteria per cubic centimeter.

While our main investigations with wastes from industrial works have been with liquors from the classes of mills mentioned, investigations have also been made upon the purification of wastes from creameries, glue works, etc., with favorable results. It must be remembered, moreover, that work of this class is carried on with considerable difficulty and inconvenience. Very often we cannot do it satisfactorily except directly at the works producing the liquor to be investigated, and, while we always welcome such opportunities, they are comparatively few in number.

DISCUSSION.

PROF. LEONARD P. KINNICUTT.* I think the Association is to be congratulated upon having Mr. Clark give to us the results of the careful experiments that have been made, under his direction, in the treatment of trade refuse. I certainly agree with him that nearly all kinds of trade refuse can be purified by bacterial treatment after dilution with domestic sewage. The question is, however, the amount of dilution necessary. This, I believe, must depend on the character of the trade refuse, and that a dilution that would be sufficient

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* Worcester Polytechnic Institute.

for refuse from tanneries and breweries would not be sufficient for wool washings, or the refuse from the preparation of wood pulp. When sufficient dilution can be obtained, undoubtedly purification by intermittent filtration is the best and cheapest method. In all cases, however, the preliminary removal of the greater part of the insoluble substances is desirable, which can be done in certain cases, as Mr. Clark has said, by roughing filters run at a very high rate, in other cases by use of the septic tank, and in certain cases by special diverse means, as copper sieves or very careful screening.

It is often very difficult, however, when manufacturing waste in very large quantities enters the sewers, to obtain good effluents by bacterial methods alone; as, for instance, in Worcester, where the sewage as it comes to the works contains from 20 to 30 parts copperas and free acid, equal to 10 parts of pure sulphuric acid in 100 000 parts of the sewage; or at Bradford, England, where the sewage contains over 400 parts of grease to the 100 000 parts.

In these cases, if the sewage, after passing through subsidence tanks to remove a part of the insoluble substance, is run upon beds, the purification is far from what is to be desired, and the beds comparatively quickly become clogged.

In a good many cases, however, there is no question that the sewage of a town, containing comparatively large quantities of trade refuse, can be satisfactorily purified by the combined action of the septic tank and intermittent filtration.

I think there is no question, however, that domestic sewage lends itself more easily to bacterial treatment than sewage containing manufacturing waste, and it is desirable to keep these products as far as possible from entering the sewers. I do not mean to say that it is by any means always the best policy to say to a manufacturer, "You must remove obnoxious impurities from your waste water before you can empty it into the sewers"; only that, if the manufacturer can be induced to do so, it much simplifies the treatment of the town or city sewage.

In England there is an attempt to prohibit obnoxious waste trade products from entering the sewers. The general law of the Rivers Pollution and Prevention Act prohibits the discharging into the sewers of solid matter that may have accumulated in subsidence tanks, but allows liquids to be so discharged, if they contain no injurious or poisonous substances.

The West Riding Pollution Commission excludes all liquids rendered poisonous, noxious, or polluted by manufacturing waste.

The City of Bradford Act declares it is not lawful for any person to suffer any refuse from any manufacturing process that would interfere with the treatment or utilization of the sewage of the city, to flow or pass into any sewer. I might say, however, at the time of my last visit to Bradford, in September, 1901, there seemed to be not the slightest attempt to enforce the law.

The London County Council prohibits the discharge of dangerous substances, especially petroleum products or residues, into the sewers.

These laws have, to a certain extent, caused the manufacturers to partially purify waste products before allowing them to pass into the sewers; but the real reason why more attention has been paid to this subject in England than in this country is that a large number of factories are found on small streams, away from sewer connections, and it is absolutely necessary that the waste products from these factories should be treated before passing into the stream.

A most interesting and instructive paper on this subject by R. A. Tatton and W. O. E. Meade-King, with the discussion that followed, is to be found in the Proceedings of The Institute of Civil Engineers, January 9, 1900. This paper takes up the treatment of the waste products from bleacheries, woolen, silk, and cotton mills, tanneries, breweries, print works, chemical works, etc. The conclusions to be drawn from the paper are, that in most cases, with the possible exception of tanneries and breweries, the waste products should receive chemical treatment before being allowed to run into bacterial beds.

During my visit of last summer to England, I studied the treatment of waste trade products, especially as regards the treatment of liquids containing wool washings and dye stuffs.

Bradford is one of the centers of the woolen trade in England, and over three hundred and seventy tons of wool are washed daily in that district. A large proportion of these washings pass untreated into the sewers, and the city authorities have as yet not found any satisfactory way of treating the sewage. The method now used, of adding sulphuric acid and passing the sewage into subsidence tanks, is very far from being efficient, and various experiments with bacterial treatment have not showed encouraging results. Various firms in the district have, however, attempted treatment of the washings before allowing them to enter into the sewer. The most efficient of these processes is that employed by John Smith & Sons, at the Field

Head Mill. The amount of water used is about one gallon to one pound of wool. These washings, which contain about two per cent. of grease, are evaporated in a Yaryam evaporator, and the grease in the concentrated liquor is removed by centrifugals. The liquid, after the grease is removed, is further concentrated and then, in a semi-solid state, run into a revolving furnace, where the organic matter that it contains is burned; and the residue, containing a considerable per cent. of potassium carbonate, is used in the manufacture of soap. By this process about eighty per cent. of the water used in the washing of the wool is recovered. This water is free from organic matter, and, containing a little ammonia, is much better than city water for washing purposes. It is also claimed that the price of the grease recovered far more than pays for the cost of treatment.

The method usually employed by the manufacturers at Bradford is to add sulphuric acid to the washings, thus cracking the grease, and passing the liquor through filters; in this way, about three fourths of the grease is recovered. The effluent contains about sixty grains of grease to the gallon.

A better method used at one or two mills is to add, besides sulphuric acid, ferric sulphate. It is claimed that the effluent from this process contains not over ten grains of grease to the gallon.

I have already occupied too much of your time, but on some other occasion may speak of the treatment of waste products from other industries, and especially refer to one large print works, where the soap liquors, the logwood liquors, and the liquor from the indigo vat, are all treated separately by chemicals, and the effluent from these processes, after being united with the liquors from the dye house, is treated on bacterial beds.

WATER SUPPLIES OF VERMONT.

BY CHARLES P. MOAT, CHEMIST, VERMONT STATE LABORATORY OF HYGIENE, BURLINGTON, VT.

[*Read November 13, 1901.*]

The State of Vermont, with its Green Mountain range extending throughout its whole length, with its many hills, its numerous streams, lakes, and ponds, together with its small population, living in many towns and villages rather than large cities, is not surpassed by any state in its natural facilities for pure water supplies. Nature has done much for the state in providing such an opportunity for safe water. Still, owing to carelessness or thoughtlessness, many of these beautiful sources have been contaminated, thus endangering other communities farther down these same streams and dependent on them for their drinking water.

Vermont differs from many of our states in being so largely made up of towns — with only six cities, the largest of which has a population of less than twenty thousand. This probably accounts for the numerous so-called public water supplies in each village, and for the few owned by the villages themselves. Most of the villages and cities are supplied by several different systems, each furnishing water to a number of families, besides the numerous domestic wells.

Since the Laboratory of Hygiene was established, in 1899, the waters of the villages and cities having the so-called public supplies, as distinct from those depending on private springs and wells, have been analyzed as often as could be done, with the result that many of these towns and cities are now trying in every way to provide safe water for their inhabitants, and to keep it safe by inspection of the sources and the surrounding country from which the supply is derived. This inspection, which we are urging them to undertake, will bring about a great change in many cases.

Although our data is not by any means as complete as I would wish, I will try and give a brief idea of the kind and quality of the water used by these public systems. No regular systematic investigation has been undertaken on any of these, further than the analy-

ses of samples at intervals more or less frequent, depending on the quality of the water and on the desire of the village or city. I shall take up the villages and cities in each county, beginning with those on the north, and following down to those on the Massachusetts line, giving a brief idea of the water used by the cities and larger villages in those counties, with an average chemical analysis of some of the larger supplies.

Grand Isle, the northwestern county of the state, comprising the large islands in Lake Champlain, depends on the lake and on private wells for its water, and has no public systems.

In *Franklin County*, the next on the northern line, Enosburg Falls and Swanton get their water from the Missisquoi River, a stream rising in the Green Mountains and flowing through northern Vermont and Canada to Lake Champlain; at Swanton, a brook showing evidences of contamination enters the stream and at times pollutes it badly. Enosburg Falls is also supplied with spring water of the Kendall system. Richford, in the same county, uses water from mountain brooks, while Bakersfield is supplied by springs. The range of the most significant constituents* of these waters is as follows, in parts per 100 000: —

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Enosburg Falls, Kendall System	.0006–.0030	.0046–.0104	.03–.24
,, ,, River System	.0036–.0080	.0096–.0254	.03–.13
Swanton	.0002–.0024	.0074–.0204	.08–.23

In *Orleans County*, the next to the eastward, spring and pond sources are most used; Barton uses the later, while Newport uses some pond water supplied by the Newport Water Company from Derby Pond, a pond one and one-quarter miles long and one-half mile wide, and also some spring water furnished by the Raymond Company. Troy gets its supplies from springs on Jay Mountain. Barton Landing also has a spring water supply.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Newport, Newport Water Company	.0024–.0122	.0062–.0190	.12–.25
" Raymond Company	.0006–.0022	.0034–.0188	.20–.30
North Troy	.0002–.0042	.0060–.0170	.05–.07
South Troy	.0018–.0036	.0060–.0112	.07–.09

In *Essex County*, the northeastern county of the state, Brighton and Island Pond have both spring and pond water; Lunenburg is supplied by two different springs; Canaan uses spring water.

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*For complete analyses, see table on page 518.

	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
Brighton	.0006–.0012	.0028–.0082	.07–.24
Canaan	.0006–.0014	.0032–.0056	.08–.12
Lunenburg, Fitzdale, No. 1	.0008–.0022	.0094–.0194	.10–.12
,, ,, No. 2	.0014–.0044	.0136–.0180	.08–.15

Coming to *Chittenden County* on the west, bordering Lake Champlain, we find various kinds of supplies. The city of Burlington uses lake water, the intake being located about two and a half miles from the city, in an opposite direction from the sewer which empties into the lake. As the tables show, the *B. Coli Communis* are found at times, though we think this is due more to the sewage polluted Winooski River entering the lake a few miles north of the city than to our own sewers. Still, if the sewage of Burlington were filtered before entering the lake, it would save the lake from one instance of contamination and in that way put off the time when Burlington will have to filter its water taken from the lake, or else go to the mountains for its supply. At times we are bothered with the taste and odor of the micro-organisms usually found in such surface waters.

Streams furnish water to Milton and Richmond, the latter getting its supply from small streams, and the former from the Lamoille River. The villages of Jericho, Underhill, and Winooski, all use spring water.

	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
Burlington, 1901	.0012–.0034	.0104–.0196	.08–.14
Underhill	.0000–.0024	.0020–.0078	
Winooski	.0006–.0024	.0118–.0278	.14–.23

In *Lamoille County* all the villages use spring water.

	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
Cambridge	.0002–.0048	.0088–.0354	.04–.17
Jeffersonville	.0002–.0034	.0082–.0212	.11–.15
Morrisville, New System	.0010–.0022	.0040–.0100	.04–.13
,, Old System	.0012–.0022	.0052–.0076	.04–.13
Stowe	.0004–.0010	.0044–.0048	.18–.21

Washington County has its large towns and cities near one another in the center of the county. The city of Barre has eleven different systems, each supplying fifteen or more families. These use water from springs, brooks, and ponds, the "city water" coming from the latter source. Montpelier is supplied by several springs owned by private parties, and by the city system using water from Berlin Pond. This latter supply we have had occasion to

inspect, and find that the city is endangered by the camps along the shores of the pond and by the unsanitary conditions in several places along the stream on its way from the pond to the Montpelier reservoir. The pond itself, two miles long and one-half mile wide, situated among the hills high above the city, would be an ideal source were the conditions changed; but the city must control the surrounding hills, prohibit camps at the pond, and correct the nuisances along the stream in order to be sure of a safe supply. At present, a single case of typhoid fever among the campers might start a serious epidemic in Montpelier, as about nine tenths of the people use the Berlin Pond water. Northfield has three systems, using waters of springs and brooks. Middlesex has three different spring supplies, as also does Waterbury, getting them from the surrounding hills. Marshfield, also, has a spring supply.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Barre	.0006–.0032	.0104–.0278	.08–.11
Middlesex, Fisher Spring	.0020–.0032	.0062–.0070	.31–.32
,, Miles Spring	.0002–.0038	.0044–.0182	.04–.08
,, Miles-Shepard Sys.	.0002–.0022	.0028–.0094	.05–.13
Waterbury	.0000–.0030	.0026–.0408	.06–.10

The villages in *Caledonia County*, on the New Hampshire line, have a varied supply. Hardwick takes its supply from a pond fed by small mountain brooks, while Lyndon and Lyndonville have four different systems. About three fourths of the latter village use the village system, which takes its water from a brook whose source is in a cedar swamp. The other systems use spring water running through open brooks to their reservoirs. St. Johnsbury has two systems, — the river system, taking the Passumpsic River water, and the Fairbanks system, with pond water from Stiles Pond, which is one mile in length and three quarters of a mile in width, situated at the base of Waterford Mountain.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Lyndonville Water Company	.0010–.0026	.0114–.0132	.10–.12
St. Johnsbury, River System	.0012–.0034	.0152–.0332	.04–.12
,, Fairbanks Sys.	.0008–.0020		.07–.09

In the county of *Addison*, on the western border of the state, we have the villages of Bristol and Middlebury and the city of Vergennes with public supplies. The first mentioned has spring water from several systems, while Middlebury and Vergennes use

EXAMINATIONS OF WATER FROM VARIOUS WATER SUPPLIES IN VERMONT.

[Parts per 100 000.]

LOCALITY.	APPEARANCE.			ODOR.	RESIDUE ON EVAPORATION.			AMMONIA.		CHLORINE.	NITRATES.	NITRITES.	HARDNESS.	BACTERIA PER C. C.	BACILLUS COLI COMMUNIS.
	Turbidity.	Sediment.	Color.		Total.	Loss on Ignition.	Fixed.	Free.	Albuminoid.						
Franklin County.															
Enosburg Falls (Kendall System)	None.	None to sl.	0.0	None to faint.	10.84	1.36	9.48	.0018	.0062	.13	.0580	.0000	7.1	100– 2 400	At times.
(River System)	None to dist.	None to h'vy.	0.2	V faint to dist.	5.85	1.35	4.50	.0035	.0138	.10	.0230	.0000	3.8	400–10 000	At times.
Richford	None to sl.	None to sl.	0.2	Faint to dist.	3.90	1.44	2.46	.0022	.0136	.09	.0600	.0001	2.2	300– 2 400	None.
Swanton (Intake)	None to dist.	Sl. to cons.	0.4	V. faint to dist.	5.40	1 32	4.08	.0014	.0124	.10	0300	.0000	3.7	250– 5 400	Us'ly pr.
Orleans County.															
Barton (Barton W. W.)	Distinct.	Cons.	0.4	Faint to dist.	5.10	1.72	3.38	.0046	.0184	.08	.0110	.0000	2.5	Av.– 4 000	At times.
Newport (Newport W Co.)	V. sl. to dist.	V. sl. to cons.	0.05	None to dist.	16.72	2.06	14 66	.0050	.0124	.18	.1140	.0002	14.0	390– 8 400	At times.
(Raymond Co.)	None to sl.	V. sl. to h'vy.	0.2	None to faint.	14.15	2.65	11.40	.0017	.0090	.25	.2700	.0000	10.1	1 000– 7 200	None.
North Troy	None to dist.	None to sl.	0.1	None to faint.	3.36	1.04	2.32	.0014	.0104	.06	.0220	.0000	2.1	214– 3 800	None.
South Troy	Sl. to dist.	Sl. to cons.	0.1	V. ft. to dist.	4.32	2 09	3.23	.0028	.0076	.08	.0300	.0000	2.8	300–11 400	None.
Essex County.															
Brighton and Island Pond	None to v. sl.	None to v. sl.	0.3	None to faint.	4.40	1.35	3.05	.0034	.0136	.15	.0060	.0000	2.4	500–12 000	None.
Canaan (Public System)	None to sl.	None to sl.	0.0	None to faint.	7.08	1.34	5.74	.0016	.0055	.11	.1070	.0000	4.7	100– 400	None.
Lunenburg (King Spring)	Very slight.	Slight.	0.0	None to v. ft.	6.52	1.52	5.00	.0012	.0082	.19	.1900	.0000	2.7	Av.– 100	None.
(Day Spring)	Very slight.	V. sl to sl.	0.0	None to v. ft.	5 76	0.84	4.92	.0030	.0116	.15	.0900	.0600	2.7	Av.– 100	None.
(Fitzdale No. 1)	Sl. to dist.	V. sl. to sl.	0.1	None to dist.	3.80	1.30	2.50	.0015	.0144	.11	.1100	.0003	1.8	100– 2 400	None.
(Fitzdale No. 2)	Sl. to dist.	Sl. to cons.	0.3	one to dist.	4.76	1.86	2.90	.0038	.0158	.12	.0400	.0000	2.8	2 300–10 000	None.
Chittenden County.															
Burlington (Tap in Lab. 1899)	None to sl.	None to v. sl.	0.2	None to faint.	6.67	2 05	4.62	.0026	.0137	.14	–	–	3.6	35– 216	At times.
(Tap in Lab. 1900)	None to sl.	None to v. sl.	0.2	None to faint.	7.20	2.16	5.04	.0040	.0140	.22	–	–	3.6	250– 336	At times.
(Tap in Lab. 1901)	None to dist.	None to v. sl.	0.2	None to dist.	6.85	1.63	5.22	.0017	.0132	.10	.0150	.0000	4.5	100– 700	At times.
Richmond	None.	None to v. sl.	0.0	None to faint.	10.32	2 00	8.32	.0016	.0068	.16	.1800	.0000	7.4	80– 100	None.
Underhill	None to v. sl.	V. sl. to sl.	0.0	V. faint to ft.	5.92	1.04	4.88	.0018	.0070	.07	.0820	.0001	4.0	100– 1 400	None.
Winooski (W. W.)	None to dist.	None – cons.	0.4	None to dist.	6.05	1.45	4.60	.0014	.0160	.16	.0230	.0001	3.7	140– 5 800	None.
Lamoille County.															
Cambridge	None to v. sl.	V. sl. to sl.	0.0	None to dist.	4 20	1 10	3.10	.0010	.0112	.11	.0110	.0000	2.6	100– 3 400	None.
(Jeffersonville System)	None to sl.	V. sl. to cons.	0.1	None to faint.	6.10	1.58	4 52	.0016	.0146	·	.1100	.0000	3.9	100– 3 600	At times.
Hyde Park (Village System).															
(Spring No. 1)	None.	None.	0.0	None to v. ft.	6.90	1.30	5.60	.0012	.0028	.12	.1800	.0000	4.0	100– 3 600	None.
(Spring No. 2)	None.	Very slight.	0.0	None to v. ft.	5 90	0 95	4 95	.1004	.0022	.12	.2000	.0000	3.7	100– 6 600	None.
(Spring No. 3)	None.	Very slight.	0.0	None to v. ft.	23.70	6.20	17.50	.0002	.0016	2.40	.8000	.0000	10.8	1 000–c'tless	None.
Morrisville (New System)	None to v. sl.	None to v. sl.	0.0	None to faint.	6.19	1.01	5.18	.0014	.0062	.11	.0600	.0000	5.1	110– 2 400	At times.
(Old System)	None to dist.	V. sl. to h'vy.	0.0	None to dist.	6.75	1.15	5.60	.0017	.0064	.11	.0560	.0000	5.3	80– 2 400	At times.
Stowe (Village System)	None to sl.	V. sl. to sl.	0.0	None to v. ft.	7.20	1.50	5.70	.0005	.0030	.26	.1580	.0000	5.6	50– 850	None.
Washington County.															
Barre (City Water)	Sl. to dist.	Sl. to heavy.	0.3	V. ft. to dist.	14.42	1.60	12.82	.0025	.0218	.10	.0150	.0000	11.7	100– 1 800	At times.
Marshfield	None to dist.	V. sl. to h'vy.	0.0	None to dist.	3.58	0.83	2.75	.0020	.0082	.11	.0990	.0002	2.3	500– 3 600	None.
Middlesex (Fisher Spring)	None to sl.	None to sl.	0.0	None to dist.	4.78	1.66	3.12	.0023	.0065	.32	.1000	.0000	2.1	–	At times.
(Miles Spring)	V. sl. to dist.	V. sl. to cons.	0.0	None to dist.	2.70	0.45	2 25	.0005	.0070	.06	.0240	.0000	1.5	350– 2 600	None.
(Miles-Shepard System)	None to v. sl.	None to sl.	0.0	None to dist.	2.25	0.47	1.78	.0007	.0062	.06	.0360	.0000	1.4	550– 2 000	At times.

Montpelier (Middle Berlin Pond)*	Dist.	Very slight.	0.1	Dist.	10.00	1.30	8.70	.0010	.0158	.10	.0050	.0000	7.6	400	None.
(Intake Reservoir)*	Dist.	Cons.	0.3	Dist.	10.60	1.80	8.80	.0032	.0202	.14	.0090	.0000	7.7	4 000	Present.
(Av. Tap in City)	Dist.	Sl. to cons.	0.3	Dist.	10.26	1.26	9.00	.0041	.0162	.12	.0060	.0000	7.9	2 750– 4 000	At times.
Northfield (R. R. System)	Dist.	Cons. to h'vy.	0.0	V. faint to ft.	9.12	0.92	8.20	.0022	.0116	.09	.0400	.0000	6.9	500– 2 100	Present.
(Dutton System)	V. sl. to sl.	Sl. to cons.	0.0	None to faint.	5.92	1.20	4.72	.0008	.0104	.07	.0380	.0000	2.0	800– 1 000	None.
(Emerson System)	Sl. to dist.	Sl. to cons.	0.1	V. faint to ft.	12.80	1.40	11.40	.0012	.0078	.07	.0820	.0000	7.4	800– 1 000	None.
Waterbury (Village System)	None to sl.	None to v. sl.	0.0	None.	4.06	0.76	3.30	.0011	.0084	.07	.0400	.0000	2.4	200– 2 000	None.
Caledonia County.															
Barnet (Public System)	None to v. sl.	V. sl. to sl.	0.0	None.	6.30	0.80	5.50	.0004	.0028	.07	.0300	.0000	5.4	Av.– 200	None.
Hardwick	Very slight.	V. sl. to cons.	0.2	None to dist.	8.88	1.16	7.72	.0006	.0072	.07	.05[illegible]0	.0000	6.0	400– 3 600	None.
Lyndon (Public System)	None.	None to sl.	0.0	None to faint.	15.60	2.00	13.60	.0014	.0046	.09	.0190	.0000	13.0	200– 1 100	At times.
Lyndonville (L. Water Co.)	V. sl. to dist.	V. sl. to cons.	0.5	Faint to dist.	14.00	2.20	11.80	.0018	.0124	.11	.0110	.0000	9.4	200– 9 600	At times.
(Railroad System)	None to v. sl.	None to v. sl.	0.0	None to faint.	15.25	1.40	13.85	.0000	.0030	.08	.0190	.0000	12.2	485– 900	None.
(L. Village System)	None to dist.	None to cons.	0.7	None to dist.	11.40	2.80	8.60	.0012	.0174	.08	.0100	.0000	7.1	500– 3 500	At times.
St. Johnsbury (River System)	Sl. to decid.	Heavy.	0.4	Faint to dist.	8.70	1.90	6.80	.0024	.0224	.10	.0240	.0000	6.3	700– 1 800	At times.
(Fairbanks System)	V. sl. to sl.	Sl. to cons.	0.4	Faint to decid.	5.08	1.68	3.40	.0014	.0194	.08	.0210	.0000	2.6	300– 1 260	None.
Addison County.															
Bristol (East St. Aq. Co.)	None.	None.	0.0	None to faint.	17.25	2.60	14.65	.0002	.0018	.12	.0090	.0000	14.6	All about same, 100–1 700	At times.
(Rock Sp. Water Co.) (No. Mt. Sp.)	None.	None to v. sl.	0.0	None to v. ft.	3.25	0.25	3.00	.0022	.00[illegible]8	.11	.0100	.0000	1.4		None.
(River Sp.)	None.	None to v. sl.	0.0	None to v. ft.	8.80	1.30	7.50	.0030	.0090	.09	.0420	.0000	7.9		None.
(Bristol Aq. Co.) (Middle Sp.)	None.	None to v. sl.	0.0	None.	4.25	0.25	4.00	.0024	.0080	.11	.0060	.0000	3.1		At times.
(North Sp.)	None.	None.	0.0	None.	4.65	0.30	4.35	.0000	.0020	.09	.0060	.0000	3.5		At times.
(South Sp.)	None.	None.	0.0	None.	4.35	0.35	4.00	.0024	.0076	.10	.0060	.0000	3.5		At times.
Middlebury (Creek System)	V. sl. to dist.	V. sl. to cons.	0.3	Faint to dist.	8.84	2.88	5.96	.0044	.0136	.18	–	–	4.0	4 200–10 000	Present.
Vergennes (City Water) [1]	None.	Cons. to hv'y.	0.6	Dist. to decid.	9.84	2.28	7.56	.0152	.0444	.09	.0300	.0001	5.4	4 000 –	Present.
(City Water) [2]	Slight.	Very slight.	0.4	Faint to dist.	9.50	1.90	7.60	.0014	.0156	.12	.0110	.0000	7.4	c'ntless.	Present.
Orange County.															
Bradford	None to sl.	V. sl. to sl.	0.1	V. ft. to dist.	6.83	1.13	5.70	.0015	.0112	.09	.0080	.0000	4.9	100– 3 200	None.
Randolph	None to sl.	None to sl.	0.0	None to dist.	10.60	1.38	9.22	.0009	.0067	.11	.1030	.0000	8.5	100– 1 000	None.
Rutland County.															
Brandon (Fern Lake)	None to dist.	None to cons.	0.0	V. ft. to dist.	11.00	3.13	7.87	.0112	.0194	.10	.0030	.0000	7.3	100– 2 000	At times.
Pittsford	None to dist.	V. sl. to cons.	0.0	None to v. ft.	9.85	1.73	8.12	.0016	.0055	.09	.0450	.0000	7.9	100– 490	None.
Poultney (Lake System)	Distinct.	Cons.	0.4	Distinct.	5.18	0.90	4.28	.0014	.0266	.08	.0050	.0000	3.9	200– 300	At times.
Proctor	V. sl. to dist.	V. sl. to sl.	0.1	V. ft. to dist.	14.86	3.49	11.37	.0026	.0124	.10	.0110	.0000	13.6	80– 9 700	At times.
Center Rutland	None to v. sl.	V. sl. to cons.	0.0	None to v. ft.	6.32	0.75	5.57	.0012	.0060	.07	.0020	.0000	4.8	100– 1 000	None.
City of Rutland	V. sl. to sl.	V. sl. to cons.	0.3	V. ft. to dist.	5.76	1.56	4.20	.015	.0100	.10	.0170	.0000	3.8	150– 6 600	Present.
Windsor County.															
Chester	V. sl. to sl.	Very slight.	0.1	V. faint to ft.	4.85	0.98	3.87	.0019	.0132	.10	.0150	.002	2.2	300– 600	None.
Hartford (Water Co.)	None to v. sl.	None to v. sl.	0.0	Faint.	7.24	0.92	6.32	.0018	.0106	.12	.0080	.0000	3.6	Very high	None.
Norwich (Norwich W. Co.)	None to v. sl.	None to cons.	0.0	None to faint.	7.37	0.69	6.68	.0010	.0052	.10	.0130	.0000	5.5	300– 2 400	At times.
(Armstrong Supply)	None to v. sl.	V. sl. to sl.	0.0	None to faint.	12.26	1.44	10.82	.0011	.0078	.15	.0750	.0000	7.9	100– 1 100	None.
Rochester (Public Sup. Sp. No. 1)	None to v. sl.	None to v. sl.	0.0	None.	4.30	0.90	3.40	.0030	.0060	.11	.1100	.0000	3.0	Av.– 300	None.
Windsor (Village System)	None.	None.	0.0	V. faint to ft.	11.84	0.96	10.88	.0014	.0014	.10	.0190	.0000	8.9	Av.– 900	None.
Bennington County.															
Arlington	None.	None.	0.0	None.	11.20	1.10	10.10	.0004	.0038	.07	.0200	.0000	8.1	200– 416	None.
Bennington (City Water)	None.	None.	0.2	None to faint.	3.02	0.96	2.06	.0032	.0096	.10	.0580	.0000	1.5	50– 500	None.
Manchester (Village System)	None.	Very slight.	0.0	Faint to dist.	2.18	0.38	1.80	.0014	.0046	.07	.0390	.0000	1.6	300– 900	None.
(Center System)	None to v. sl.	None to v. sl.	0.0	Faint to dist.	4.10	0.54	3.56	.0008	.0044	.06	.0370	.0001	3.1	110– 960	None.
Windham County.															
Bellows Falls (Minard Pond Water)	Distinct.	Sl. to heavy.	0.2	Faint to dist.	3.20	1.11	2.09	.0022	.0164	.11	.0030	.0000	1.3	960– 7 600	Present.
Brattleboro (West River)	Slight.	V. sl. to sl.	0.3	V. faint to ft.	2.76	1.16	1.60	.0011	.0112	.09	.0070	.0000	0.8	500– 800	None.
(Western Aqueduct)	None to v. sl.	None to v. sl.	0.0	None to faint.	11.18	2.22	8.96	.0009	.0034	.29	.2280	.0000	7.8	100– 4 800	None.

*Taken on same day.

[1] Average Spring Analysis.

[2] Average Summer Analysis.

the water from Otter Creek, a small, highly-contaminated stream, carrying the sewage of Rutland and numerous towns before it reaches Middlebury. However, Middlebury is now putting in a new system of spring water from sources in the Green Mountains.

The towns of Randolph and Bradford in *Orange County* use spring and brook water, respectively.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Bradford	.0002–.0034	.0060–.0168	.06–.12
Randolph	.0002–.0014	.0032–.0078	.08–.14

In *Rutland County*, Brandon and Poultney use lake waters from Fern Lake and Lake St. Katherine, the latter being 5 by 1.5 miles in extent. Proctor uses spring water, and the city of Rutland uses water from mountain brooks which have their sources in the Green Mountains. This is another supply whose streams should be controlled by the city and inspected at frequent intervals. Center Rutland gets its supply from springs in the neighboring hills.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Brandon	.0030–.0220	.0186–.0218	.07–.09
Pittsford	.0014–.0020	.0032–.0082	.08–.12
Proctor	.0006–.0048	.0116–.0146	.08–.12
Rutland (City)	.0008–.0024	.0064–.0142	.07–.11

Windsor County, on the eastern border, is made up of small towns all using spring water.

	Free Ammonia.	*Albuminoid Ammonia*	*Chlorine.*
Chester	.0008–.0032	.0092–.0190	.08–.11
Hartford	.0010–.0072	.0078–.0152	.10–.20
Norwich, Village System	.0000–.0026	.0044–.0062	.10–.13
,, Armstrong System	.0010–.0018	.0072–.0084	.14–.16

Bennington County, on the southern border, has its towns all using spring water, Manchester getting its supply from springs on Equinox Mountain.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Bennington	.0018–.0048	.0078–.0108	.04–.16
Manchester, Village System	.0006–.0028	.0044–.0188	.03–.13
,, Center System	.0004–.0016	.0006–.0078	.03–.09

The two villages in *Windham County*, the last on the southern border, having public supplies are, Bellows Falls, taking its supply from Minard Pond, and Brattleboro, using river water from West River and spring water in its so-called Western Aqueduct Supply.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Bellows Falls	.0016–.0036	.0152–.0204	.10–.15
Brattleboro, Western Aqueduct	.0000–.0024	.0014–.0044	.25–.34
,, West River	.0006–.0016	.0090–.0136	.08–.11

As will be noticed in the tables, the chlorine in most cases is below 0.10 parts in 100 000; and although we are not yet prepared to give the normal chlorine for Vermont, still it seems from our data at present as if it varied but little in different parts of the state, and is very similar to that in western Massachusetts.

While these results are brief and incomplete, still they may give some better idea of some of the water supplies of Vermont, and thus increase our knowledge of the waters of New England.

FALL OF THE FAIRHAVEN WATER TOWER.

AN INFORMAL TALK BY R. C. P. COGGESHALL, SUPERINTENDENT NEW BEDFORD WATER WORKS.

[*At the Meeting of November 13, 1901.*]

The city of New Bedford is located upon the west side of the Acushnet River. The town of Fairhaven is upon the east side directly opposite. One of the principal features of the water works of this town was the water standpipe, which was a landmark familiar to every one thereabouts and visible for many a mile in every direction. This was located just north of the highway leading east from the center of the town and about three-quarters of a mile distant from that center.

This tower attracted considerable attention at the time it was erected in 1893, and has been the model of several similar structures. It was fully described in a paper, illustrated by drawings, presented to this Association by Mr. Joseph K. Nye, superintendent of the Fairhaven Water Works, in 1894.*

This tower completely collapsed on Saturday afternoon last, November 9, at about four o'clock. I have obtained several photographs of the wreckage as it now lies, which I thought might be of interest to you. I also have a view of the tower as it appeared before the disaster. These photographs will illustrate the condition of things better than any verbal description I can give.

This first picture, Plate I, is a view showing the standpipe as it had stood since its erection, seven or eight years ago. Plate II, Fig. 1, is a view taken from the top of the draw of the new bridge connecting Fairhaven with New Bedford, and in the distance you will see how distinctly the standpipe cuts the horizon.

The following data may be of interest: —

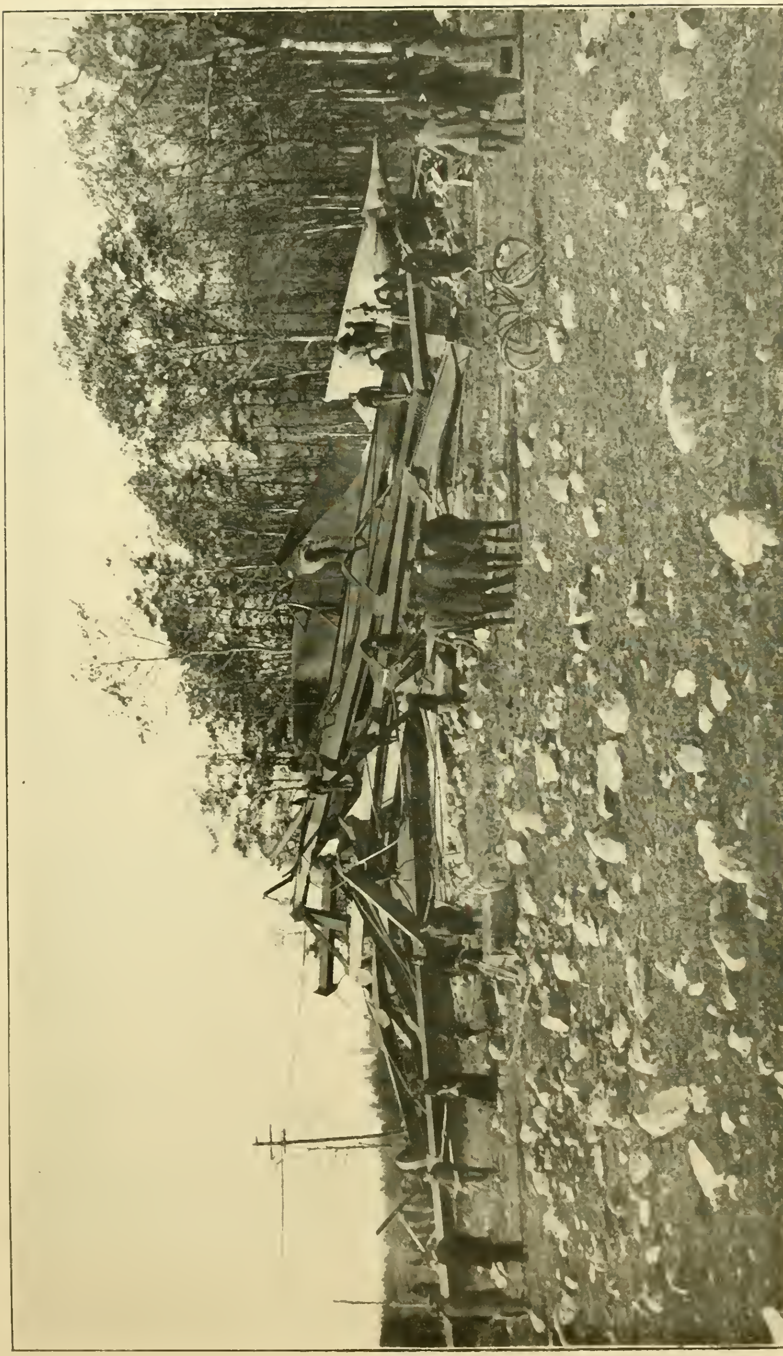
Total height of tower	200 feet.
Length of supporting legs	100 feet.
Height of tank	50 feet.

*JOURNAL, Vol. viii, p. 175. It should be noted, however, that the standpipe as built differed in several important details from the drawings published.

Fairhaven Standpipe.

FIG. 1.—VIEW FROM NEW BEDFORD-FAIRHAVEN BRIDGE. STANDPIPE IN THE DISTANCE.

FIG. 2.—WRECK OF FAIRHAVEN STANDPIPE.



WRECK OF FAIRHAVEN STANDPIPE.

FIG. 1.—BOTTOM OF WRECKED FAIRHAVEN STANDPIPE.

FIG. 2.—WRECK OF FAIRHAVEN STANDPIPE.

FIG. 1.—WRECK OF FAIRHAVEN STANDPIPE.

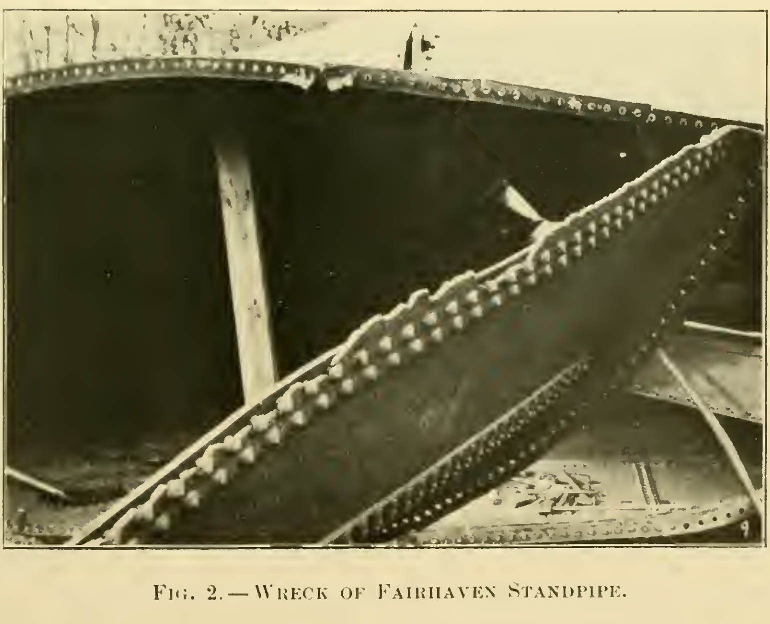


FIG. 2.—WRECK OF FAIRHAVEN STANDPIPE.

Diameter of tank	35 feet.
Height of roof	50 feet.
Capacity when full	383 000 gallons.

There were apparently no unusual conditions at the time of the disaster. There was little or no wind, and the tank lacked considerable of being full. There has been more or less leakage from the bottom joints in the past; but I understood that this had been remedied. The general opinion seems to be that the conical bottom opened up in one of its seams, allowing the heavy mass of water to drop upon the foundation, knocking out the foundation of the supporting legs. This caused the whole structure to shut up like a knife. The several photographs show how the stone wall which marked the line of the company's lot was distributed around the pasture in the foreground. This wall was completely swept away. A horizontal rotary motion was imparted to the tank as it fell, as is shown by the twist and direction in the bending of the supports.

Two boys were riding by on a tandem bicycle when the break occurred. One jumped from the wheel and was caught by the torrent of water and carried over the stone wall into the field on the south side of the road. His companion stuck to the wheel until it struck the wall, when he, too, was landed into the open field. A man driving a heavy cart was lifted from his seat by the flood and landed at a considerable distance. While none was killed, all three received injuries of a more or less serious nature.

Plate III is a view of the wreck from a position in the field east of the foundation. The roadway is at the left side. A stone wall which marked the line of the water company's lot is seen distributed about the pasture in the foreground. Among this assortment of rocks is a portion of the rubble masonry foundation. At the left of the center of the picture is seen one of the two-ton blocks that was kicked by a leg as it was ripped from its anchorage. The fallen legs, some broken, others twisted and bent, lie in a pile across the center of the picture. Just behind is the side of the tank, the bottom being toward the roadway at the left, and the top is seen over the heads of a group of four men in the middle ground of the picture, with a part of the gallery visible. The tank as it fell revolved around on its own axis more than half way, and while one section of the conical bottom lies in the street, the other part is folded under the heap. The steep conical roof, of one-eighth-inch galvanized plate, is seen in the upper right quarter of the photograph, the tip toward the north.

Such a disaster always brings forth a variety of opinions as to the cause. This is no exception. A number of theories have been advanced. I think, however, we shall wait with interest for the reports of the experts who now have the matter under investigation.

AN INFORMAL ADDRESS.

BY JOHN O. HALL, MAYOR, QUINCY, MASS.

[*Delivered November 13, 1901.*]

Mr. President and Gentlemen of the New England Water Works Association, — It was with a great deal of diffidence that I consented, at the request of your President, to say a word this afternoon, because I always feel very insignificant when I meet with the members of the New England Water Works Association. It has been a source of regret to me that my line in life did not lead me to deal with actual, material things; that I was not permitted to be a mechanic in the true sense; that I was not permitted to study those sciences which deal with the practical and material matters of life. It has been my fortune at one or two of your meetings to listen to essays which were illustrated by diagrams, — cross sections of engines and pumps and matters of that sort, — and my absolute ignorance of things of that kind led me to feel my insignificance more than ever. Taking up a copy of the JOURNAL, a short time since, I found in it an article illustrated with a diagram — a cross section, I think, of a pump — and I resolved to make myself master of the article, with the help of the diagram and the dimensions given, but after a few minutes' study I abandoned the attempt in despair. It was "hieroglyphics" to the last degree to me. Not only was I not able to comprehend it, but I was utterly unable to get the first inkling of what it meant. And then my insignificance, as I remembered my experience with the members of the New England Water Works Association, impressed me more forcibly than ever.

I have a great respect for the members of the New England Water Works Association. I have a great respect for the men who have made the tap in the sink possible, for I have a very distinct recollection of wrestling in my younger days with the pump. When you go out into the back shed at night, with the thermometer down below zero and the frost sending its fingers under the back shed door, and pump and pump and pump and pump and pump and pump, in order that you may have water for the

preparation of the morning breakfast, and when you are all ready to see the water come from the spout, you hear a sinking sound 'way down somewhere under the ground and a faint last gurgle, and realize that the bottom box is out of order and the water is gone for good. I assure you that you can realize that the tap in the sink is a luxury indescribable. I have a great respect for, and my emotions are deeply stirred when I read or when I think of, the "old oaken bucket that hung in the well." But at four o'clock on a winter morning, with the ground cased in ice, if you take the bucket and start for that well, and you find yourself sliding to that well on the fattest part of your body, with your head and your heels in the air and the bucket gone from you, you know not where, then your respect for the men who made the tap in the sink possible will increase an hundredfold.

I have been greatly pleased in listening to the papers this afternoon, because they show the paternal care of governments exercised for the benefit of the citizens. I listened yesterday to papers in reference to the construction of highways, and the remark was made that all sands were alike; and yet before the essay was completed I realized that there were varieties of sand, and those varieties were differently useful in different cases. At one time people supposed that water was water, but we have come to realize that there are great differences in water and to consider it scientifically, so that by protecting the purity of the water we are doing much for the health and comfort of our communities. This has been largely the result of the work of such associations as yours, and of the work of men who have made a scientific study of these things, and advanced step by step from the inconvenience of our original civilization up to the scientific basis of our civilization to-day. And when I think that it is possible for a community to contribute men and money and materials so that a whole state can be classified as to its water-producing facilities and to the qualities of the water produced, so that all affairs of the communities of the state can be so administered that they shall not contribute to the injury of those water facilities, and in the process of civilization everything that is detrimental to the quality of the water and, therefore, to the citizens of the state who use it, can be removed — and this not at the expense of the individual, but, by the assistance of science, to the profit of the individual, so that the waters are rendered purer and at the same time he secures additional profit to his manufacture; so that the board of engineers

furnishing a community with pure water are the servants of the community in advancing civilization, and also the servants of the individuals of the community by increasing their sources of wealth, — I realize that you gentlemen are indeed adding to the general welfare, to the public health, and to the building up of a better community.

There are two sides to this question of pure water: first, as to the quality; second, as to the distribution. You want to distribute water of a pure quality, but in that work you encounter numerous difficulties, some of them seemingly insurmountable. The nature of your country, the location of the community that you wish to supply, the extent of your supply, and the increased demand on the supply that you have available, are problems which call upon you for the exercise of your highest powers. One difficulty which you encounter, aside from the physical difficulties to be overcome, is to secure the means wherewith to accomplish what you desire to do. And in that direction we, who are not skilled engineers, can bear our part and can assist and serve in the method and in the manner and in the extent of the appropriations which can be made and must be made by the governmental department of any community. One obstacle is often the lack of harmony between the engineer, the practical superintendent, and the legislative board which controls the appropriations. You consult with your executive, and in your wisdom and experience and knowledge forecast the entire situation; but the legislative board refuses to appropriate the money for that which your wisdom teaches you should be done, while it may furnish you with an appropriation for the accomplishment of that which you do not desire and which is not proper at that stage of the development of the enterprise. Therein lies the duty and the opportunity of those who hold such positions as I do; and I assure you that the benefits arising from an intimate acquaintance with an association of this sort will enable one the better to accomplish the full and perfect and complete supply of the citizens with water of pure quality and generous quantity. The paternal nature of our governments, I think, is shown in the readiness and the facility with which they so often contribute to your wants. It is not so much a question of penuriousness that leads governments to misappropriate or not to appropriate a sufficient sum, as it is a lack of knowledge, a lack of confidence, a lack of community of coöperation in performing the labor which rests upon us; and, so far as I am concerned, I am glad to

see that there is an increased desire, determination, and purpose to coöporate in the promotion of the public welfare and in the development of those things which tend to the prosperity and health of our communities. We are making great progress; we have calls without number, and we are appalled sometimes at the stupendous work which is before us, and discouraged at our lack of progress; but when we compare the facilities which we have to-day and measure the great results which we are accomplishing, with the condition of affairs a generation or two ago, we are infinitely encouraged. And I believe the position which we hold to-day will enable us in another generation to produce results which will make the enjoyment of living upon this earth something beyond the contemplation or comprehension of the men of to-day.

PROCEEDINGS.

November Meeting.

Young's Hotel, Boston, Mass.
November 13, 1901.

President Crandall in the chair.

The attendance was as follows: —

Members.

Charles H. Baldwin, Lewis M. Bancroft, M. N. Baker, Joseph E. Beals, James F. Bigelow, Dexter Brackett, Edwin C. Brooks, George A. P. Bucknam, G. L. Chapin, John C. Chase, Harry W. Clark, Freeman C. Coffin, R. C. P. Coggeshall, F. H. Crandall, M. F. Collins, Arthur W. Dean, Jasper A. Fitch, Frank L. Fuller, Stephen DeM. Gage, J. C. Gilbert, Albert S. Glover, E. H. Gowing, Frank E. Hall, John O. Hall, J. C. Hammond, Jr., L. M. Hastings, Horace G. Holden, J. W. Kay, Willard Kent, Patrick Kieran, L. P. Kinnicutt, C. F. Knowlton, A. E. Martin, Frank E. Merrill, Leonard Metcalf, C. P. Moat, J. W. Moran, Frank L. Northrop, H. N. Parker, J. B. Putnam, W. H. Richards, W. W. Robertson, Charles W. Sherman, George A. Stacy, Charles N. Taylor, Robert L. Thomas, H. L. Thomas, W. H. Thomas, D. N. Tower, G. W. Travis, W. H. Vaughn, Charles K. Walker, C.-E. A. Winslow, George E. Winslow.

Associates.

Harold L. Bond & Co., by Harold L. Bond; Builders' Iron Foundry, by F. N. Connet; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; International Steam Pump Co., by George J. Foran; Hersey Mfg. Co., by Albert S. Glover and James A. Tilden; Henry F. Jenks; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; A. P. Smith Mfg. Co., by W. H. Van Winkle; Union Water Meter Co., by J. P. K. Otis and Frank L. Northrop; United States Cast Iron Pipe and Foundry Co., by L. R. Lemoine.

Guests.

John H. Cook, East Jersey Water Co., Paterson, N. J.; H. V. Macksey, Boston Water Works, Boston, Mass.; F. B. Skinner, Rockville, Conn.;

W. J. Welch. Boston Water Works, Boston, Mass.; Charles A. Donovan, Water Commissioner, Lawrence, Mass.; Frederick A. Beals, Water Registrar, Everett, Mass., and E. P. Walters, Metropolitan Water Works, Boston, Mass.

Mr. R. C. P. Coggeshall, of New Bedford, was called upon by the President to say something in regard to the collapse of the Fairhaven water tower, and he responded by a brief description of the tower and its wreck, illustrating his remarks by numerous photographs.

The first paper of the afternoon was by H. W. Clark, chemist, Massachusetts State Board of Health, on "Pollution of Streams by Manufactural Wastes — Methods of Prevention."

Prof. L. P. Kinnicutt, of Worcester, also spoke upon the same subject.

Mr. Charles P. Moat, chemist, Vermont State Laboratory of Hygiene, Burlington, Vt., then read a paper on "Water Supplies of the State of Vermont."

Mayor John O. Hall, of Quincy, then, by invitation of the President addressed the Association.

The following new members were elected: —

Herman W. Spooner, Gloucester, Mass., Engineer of Construction of Water Works.

George F. West, Portland, Me., Manager of Water Works.

Walter M. Scott, Charlottetown, P. E. I., Engineer.

Edward W. Bemis, Cleveland, Ohio, Superintendent Cleveland Water Works.

Edwin A. Fisher, Rochester, N. Y., City Engineer.

Adjourned.

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NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XVI. March, 1902. No. 1.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

CONSTITUTION OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

[*Adopted September 19, 1900.*]

ARTICLE I.

NAME AND OBJECT.

SECTION 1. The name of this society shall be THE NEW ENGLAND WATER WORKS ASSOCIATION.

SECT. 2. Its objects shall be the advancement of knowledge relating to water works and water supply, and the encouragement of social intercourse among water works men.

ARTICLE II.

SECTION 1. The membership of the Association shall consist of Members, Honorary Members, and Associates.

SECT. 2. Water works superintendents or other executive officers, commissioners or members of Water Boards, hydraulic engineers, sanitarians or other persons qualified to aid in the advancement of knowledge relating to hydraulic questions, shall be eligible as Members.

SECT. 3. Members only shall be eligible to office and entitled to the right to vote.

SECT. 4. Associates shall be firms or representatives of firms engaged in dealing in supplies used by water works.

SECT. 5. Members hereafter elected engaging in the business of furnishing water works supplies shall cease to be Members of the Association and their names shall be transferred to the list of Associates.

SECT. 6. Associates shall be entitled to representation at each meeting of the Association, but shall not be entitled to vote or to take part in any discussion unless permission is given by the meeting.

SECT. 7. Honorary Members shall be men eminent in some line of work connected with hydraulic engineering or water supply.

SECT. 8. Members shall be classed as Resident or Non-Resident; the

former comprising residents of the New England States, all others being Non-Resident Members.

ARTICLE III.

ADMISSIONS AND EXPULSIONS.

SECTION 1. An application for admission to the Association as Member or Associate shall embody a concise statement of the candidate's qualifications for membership, and shall be endorsed by two Members of the Association.

SECT. 2. Applications for membership shall be considered by the Executive Committee, who shall present them to the Association for ballot, provided a majority are in favor of such action.

SECT. 3. Election to membership shall be by ballot, and shall require two thirds of the ballots cast.

SECT. 4. Members and Associates elect shall subscribe their names to the Constitution by signing a form to be furnished by the Secretary.

SECT. 5. Any person who shall be in arrears to the Association for two years' dues shall be notified by the Secretary that if payment is not made within three months his name will be dropped from the roll; and if such arrears are not paid within the time specified, the Secretary shall erase the name from the membership list.

SECT. 6. A member of any grade may withdraw from the Association by giving written notice to the Secretary and settling all indebtedness to the Association.

SECT. 7. A member of any grade may be expelled from the Association upon the recommendation of the Executive Committee, adopted by a two-thirds vote of the members present and voting at any regular meeting.

ARTICLE IV.

DUES.

SECTION 1. The Initiation Fee shall be —

For Resident Members	$5.00
For Non-Resident Members	3.00
For Associates	10.00

SECT. 2. The Annual Dues shall be —

For Members	$3.00
For Associates	15.00

which shall include a subscription to THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

SECT. 3. A person transferred from the grade of Member to that of Associate shall not be assessed an additional initiation fee, but shall be liable for dues as an Associate.

ARTICLE V.

OFFICERS.

SECTION 1. The officers of this Association shall be a President, six Vice-Presidents, not more than three of whom shall be residents of the same State, a Secretary, and a Treasurer; these, together with the Editor and Advertising Agent of THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION and three other Members, shall constitute the Executive Committee, in whom the government of the Association shall be vested.

SECT. 2. The term of office of all officers and committees shall be one year, but shall continue until their successors are duly elected.

SECT. 3. There shall also be a Finance Committee of three Members of the Association other than members of the Executive Committee.

SECT. 4. All officers and committees shall assume their duties immediately after the close of the meeting at which they have been elected.

ARTICLE VI.

DUTIES OF OFFICERS.

SECTION 1. The President shall have a general supervision of the affairs of the Association. He shall preside at meetings of the Association and of the Executive Committee. In case of his absence or a vacancy in his office, the Vice-Presidents in order of seniority shall discharge his duties.

SECT. 2. The Executive Committee shall have full control of the management of the Association, subject to the action of the Association at any meeting. They shall make the necessary arrangements for all meetings, and shall have power to expend the funds of the Association, provided that no indebtedness shall be incurred in excess of the funds in the hands of the Treasurer. All questions in Executive Committee shall be decided by a majority vote, and six members shall be a quorum. The Executive Committee shall hold meetings at the call of the President, or, in his absence or inability to serve, at the call of the senior Vice-President.

SECT. 3. The Secretary shall conduct the official correspondence of the Association, shall collect and receipt for all fees and dues, and transmit the same to the Treasurer quarterly, taking his receipt therefor; he shall issue notices of all meetings of the Association at a date not less than two weeks prior to the time appointed for such meetings. He shall make a report to the Association at the annual meeting of the general condition of the Association and especially of changes in the membership.

SECT. 4. The Treasurer shall receive from the Secretary all moneys collected by him for the Association, giving his receipt therefor, and shall pay all demands against the Association when approved by the President. He shall keep a proper account of all receipts and expenditures, and shall make a report to the Association, at the annual meeting, of his doings as

Treasurer during the year preceding, together with a statement of the financial standing of the Association.

SECT. 5. The Finance Committee shall meet on or before the day of the annual meeting, and shall audit the accounts of the Secretary and Treasurer. They shall hold such other meetings as the interests of the Association may require.

SECT. 6. The proceedings of the Association shall be published as THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, which shall be issued quarterly, under the direction of a Board of Editors, consisting of the President and Secretary, *ex officiis*, and the Editor and Advertising Agent chosen by ballot. The Journal shall contain such portion of the record of any meeting as the Board of Editors may deem it expedient to publish, as well as any other articles which they shall consider of interest to the Association.

SECT. 7. The Editor of THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION shall, under the direction of the Board of Editors, keep and prepare for publication all matters intended to be printed in the Journal, and shall act as the executive officer of the Board of Editors. He shall present a report at the annual meeting, showing in detail the cost of publication of the Journal and the receipts from advertising and subscriptions.

ARTICLE VII.

NOMINATION AND ELECTION OF OFFICERS.

SECTION 1. At the business meeting during the annual convention the Association shall elect or appoint, in such manner as may be approved by the meeting, a Nominating Committee of five members, who shall present a report before the first day of November, in the form of a list of nominations for officers for the ensuing year. This report shall be printed and mailed by the Secretary to the membership of the Association.

SECT. 2. At any time before December 1, any ten or more Members of the Association may send to the Secretary additional nominations signed by such Members.

SECT. 3. The Secretary shall issue a printed ballot on the fifteenth day of December, which shall contain the nominations made by the Nominating Committee and such other nominations as may have been received by him in accordance with Section 2. This ballot shall be mailed to all members entitled to vote.

SECT. 4. Ballots may be sent by mail to the Secretary or handed to him directly. They must be enclosed in two sealed envelopes, and the outer envelope shall be endorsed by the voter's signature.

SECT. 5. The polls shall be closed one hour after the time of opening the Annual Meeting, and the ballots shall be canvassed by tellers appointed by the presiding officer. The persons receiving the highest number of votes for the offices for which they are candidates shall be declared elected.

ARTICLE VIII.

MEETINGS.

SECTION 1. A Convention of the Association for the reading and discussion of papers and for social intercourse shall be held annually at such time and place as may be determined by the Executive Committee.

SECT. 2. There shall be two general business meetings of the Association each year; first, the annual meeting, which shall be held in Boston on the second Wednesday in January, and at which the annual reports for the year ending December 31 shall be presented, and the ballot for officers canvassed; and second, a business meeting during the annual convention.

SECT. 3. In addition to the above, business meetings shall be held on the second Wednesday of the months of November, December, February, and March, and, at the discretion of the Executive Committee, in June.

SECT. 4. At any business meeting of the Association, twenty members shall constitute a quorum.

SECT. 5. All regular meetings of the Association, except the annual convention, shall be held in Boston, unless otherwise voted by the Executive Committee.

SECT. 6. Special meetings of the Association may be held at the call of the President. At special meetings no applications for membership shall be considered, and no business shall be transacted unless announced in the call for the meeting and on the recommendation of the Executive Committee.

SECT. 7. Meetings of the Executive Committee shall be held before each business meeting of the Association and at such other times as the President may deem necessary.

ARTICLE IX.

AMENDMENTS.

SECTION 1. Proposed amendments to this Constitution must be submitted in writing to the Executive Committee, and shall be presented to the Association at a regular meeting, if so decided by vote of the committee. It shall be the duty of the Executive Committee to bring before the Association any proposed amendment at the written request of ten Members.

SECT. 2. Announcements of a proposed amendment which is recommended by the Executive Committee, or by ten Members of the Association, shall be given by printing the amendment in the notices of the regular meeting. A two-thirds vote of the members present and voting shall be necessary for the adoption of an amendment.

OFFICERS

OF THE

New England Water Works Association.

1902.

PRESIDENT.

FRANK E. MERRILL.

VICE-PRESIDENTS.

CHARLES K. WALKER.
JAMES BURNIE.
EDWIN C. BROOKS.
H. O. SMITH.
WILLIAM B. SHERMAN.
J. C. HAMMOND, JR.

SECRETARY.

WILLARD KENT.

TREASURER.

LEWIS M. BANCROFT.

EDITOR.

CHARLES W. SHERMAN.

ADVERTISING AGENT.

ROBERT J. THOMAS.

ADDITIONAL MEMBERS OF EXECUTIVE COMMITTEE.

PATRICK KIERAN.
GEORGE A. STACY.
HORACE G. HOLDEN.

FINANCE COMMITTEE.

A. W. F. BROWN.
WILLIAM F. CODD.
J. W. CRAWFORD.

PAST PRESIDENTS.

*JAMES W. LYON, 1882–83.
FRANK E. HALL, 1883–84.
GEORGE A. ELLIS, 1884–85.
ROBERT C. P. COGGESHALL, 1885–86.
*HENRY W. ROGERS, 1886–87.
*EDWIN DARLING, 1887–88.
*HIRAM NEVONS, 1888–89.
DEXTER BRACKETT, 1889–90.
*ALBERT F. NOYES, 1890–91.
HORACE G. HOLDEN, 1891–92.
GEORGE F. CHACE, 1892–93.
*GEORGE E. BATCHELDER, 1893–94.
GEORGE A. STACY, 1894–95.
DESMOND FITZGERALD, 1895–96.
*JOHN C. HASKELL, 1896–97.
WILLARD KENT, 1897–98.
FAYETTE F. FORBES, 1898–99.
BYRON I. COOK, 1899–1900.
FRANK H. CRANDALL, 1901.

* Deceased.

LIST OF MEMBERS,

WITH ADDRESS AND DATE OF ELECTION.

[*Corrected to February 1, 1902.*]

NAME.	Date of Election.
Adams, John D. Supt. Water Works, Provincetown, Mass.	Sept. 8, 1897
Allen, Charles A., C. E. 44 Front Street, Rooms 109, 110, Worcester, Mass.	June 16, 1886
Allen, Charles F. Treasurer Water Co., Hyde Park, Mass.	June 16, 1886
Amyot, John A., M. B. Bacteriologist to the Provincial Board of Health of Ontario, 305 Joseph Street, Toronto, Canada.	Nov. 14, 1900
Anderson, J. M. 246 Pleasant Street, Worcester, Mass.	Jan. 9, 1901
Andrews, Frank A. Assistant Supt. Pennichuck Water Works, Nashua, N. H.	Dec. 14, 1887
Anthony, Charles, Jr. Casilla 1045, Buenos Aires, South America.	June 12, 1901
Appleton, Francis E. Paymaster Locks & Canals Co., Lowell, Mass.	Dec. 8, 1897
Armstrong, S. G., C. E. 1 Kimberly Villa, Harrington Street, Cape Town, South Africa.	Feb. 13, 1895
Babcock, Stephen E. Water Works and Hydraulic Engineer, Little Falls, N. Y.	June 12, 1886
Bacot, R. C., Jr. Supt. Meter Dept., P. O. Box 221, Port Chester, N. Y.	Dec. 12, 1888
Badger, Frank S. 28 Bellevue Street, Lowell, Mass.	June 10, 1896
Bagnell, Richard W. Plymouth, Mass.	Dec. 21, 1882
Bailey, E. W. City Engineer, Somerville, Mass.	Dec. 11, 1895
Bailey, Frank S. State Board of Health, State House, Boston, Mass.	Sept. 8, 1897
Bailey, George I. Consulting Engineer, 51 State Street, Albany, N. Y.	Dec. 14, 1892
Baker, M. N. Associate Editor "Engineering News," 220 Broadway, New York City.	Sept. 18, 1901
Baldwin, Charles H. 159 Franklin Street, Boston, Mass.	June 17, 1887
Bancroft, Lewis M. Supt. Water Works, Reading, Mass.	Jan. 8, 1890
Barbour, Frank A., C. E. 1120 Tremont Building, Boston, Mass.	Jan. 10, 1894

Name.	Date of Election.
Barnes, Roland D., C. E. 23 Spring Street, Malden, Mass.	June 14, 1899
Barrus, George H. Consulting Steam Engineer, 12–20 Pemberton Building, Pemberton Square, Boston, Mass.	Jan. 14, 1891
Bartlett, Charles H., C. E. 607 Pemberton Building, Bostou, Mass.	Feb. 8, 1893
Bartlett, R. S. Supt. Water Works, Norwich, Conn.	Jan. 13, 1897
Bassett, Carroll Ph. Treasurer Water Co., Summit, N. J.	June 13, 1889
Bassett, George B., C. E. 363 Washington Street, Buffalo, N. Y.	Sept. 10, 1897
Batchelder, George W. Water Registrar, Worcester, Mass.	June 14, 1899
Batcheller, Francis Water Commissioner, North Brookfield, Mass.	Jan. 10, 1894
Bates, Oren B. Clinton, Mass.	Sept. 11, 1895
Bates, Hon. Theodore C. 29 Harvard Street, Worcester, Mass.	Jan. 10, 1894
Beals, Joseph E. Supt. Water Works, Middleboro, Mass.	June 16, 1886
Beardsley, Joseph C. 2d Asst. Engr. Cleveland Water Works, Cleveland, Ohio.	Sept. 18, 1901
Beasom, C. B., C. E. 248 Tremont Street, Newton, Mass.	Dec. 12, 1894
Bemis, Edward W. Supt. Water Works, Cleveland, Ohio.	Nov. 13, 1901
Bennett, Thomas H. Supt. Water Works, Oswego, N. Y.	March 14, 1900
Benzenberg, G. H. Milwaukee, Wis.	June 9, 1892
Berkey, John A. President Electric and Water Co., Little Falls, Minn.	Feb. 8, 1893
Bettes, Charles R. Chief Engineer, Queen's County Water Co., Far Rockaway, N. Y.	Dec. 9, 1896
Betton, James M. 10 East 16th Street, New York City.	Jan. 8, 1902
Bigelow, James F. City Engineer, Marlboro, Mass.	Sept. 11, 1895
Birkinbine, Henry Hydraulic Engineer, 124 East Market Street, York, Pa.	June 17, 1887
Bisbee, Forrest E. Supt. Water Works, Auburn, Me.	Sept. 11, 1895
Bishop, George H., C. E. 129 Main Street, Middletown, Conn.	June 16, 1886
Bishop, Watson L. Supt. Water Works, Dartmouth, N. S.	March 8, 1893
Blackmer, James W. Supt. Water Works, Beverly, Mass.	March 8, 1899

NAME.	Date of Election.
Blossom, William L., C. E. 355 Washington Street, Brookline, Mass.	Dec. 13, 1893
Boggs, Edward M. Consulting Civil and Hydraulic Engineer, 534 Stimpson Block, Los Angeles, Cal.	Dec. 11, 1889
Bowers, George City Engineer, Lowell, Mass.	March 9, 1892
Boyer, Francis H. 13 Highland Avenue, Somerville, Mass.	June 12, 1901
Brackett, Dexter Engineer Distribution Dept., Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	April 21, 1885
Bradley, R. H. Supt. Water Works, LeSueur, Minn.	Dec. 14, 1892
Brinsmade, Daniel S. President and Engineer Ousatonic Water Co., Birmingham, Conn.	Sept. 19, 1883
Broatch, J. C. Supt. Water Works, Middletown, Conn.	April 21, 1885
Brooks, Edwin C. Supt. Water Works, Cambridge, Mass.	Feb. 10, 1897
Brooks, Fred 31 Milk Street, Boston, Mass.	Feb. 8, 1899
Brown, A. W. F. Water Registrar, Fitchburg, Mass.	June 17, 1887
Brown, J. Henry 3 Tremont Street, Charlestown, Mass.	Sept. 19, 1883
Brown, Walter I. Water Registrar, Bangor, Me.	June 11, 1896
Brownell, Ernest H., C. E. Brownell Block, 107 Westminster Street, Providence, R. I.	Jan. 11, 1893
Bucknam, George A. P. Supt. Water Works, Norwood, Mass.	June 10, 1891
Burke, James E. Sec'y, Treas., and Supt. Princeton Water Co., Princeton, N. J.	Sept. 11, 1895
Burley, Harry B. 31 Milk Street, Room 55, Boston, Mass.	Dec. 14, 1892
Burnham, Albert S. Supt. Water Co., Revere, Mass.	June 13, 1888
Burnie, James Supt. Water Co., Biddeford, Me.	June 11, 1890
Burns, Clinton S. 409 Postal-Telegraph Building, Kansas City, Mo.	Dec. 12, 1900
Burr, William H. Professor of Civil Engineering, Columbia University, and Consulting Engineer, New York City.	Feb. 16, 1894
Burse, A. H. Supt. Water Works, Pittsfield, Me.	Sept. 16, 1898
Bush, Edward W., C. E. Ætna Life Building, Hartford, Conn.	Feb. 13, 1895
Butler, J. Allen Supt. Portland Water Co., Portland, Conn.	June 10, 1891

Name.	Date of Election.
Cairns, R. A. City Engineer, Waterbury, Conn.	Feb. 13, 1895
Card, Huber D. City Engineer, Willimantic, Conn.	Jan. 8, 1896
Carpenter, L. Z. Attleboro, Mass.	Dec. 13, 1899
Carroll, Fred B. Rumford Falls, Me.	Dec. 12, 1888
Cassell, George Supt. Water Works, Chelsea, Mass.	March 8, 1899
Caulfield, John Sec'y Water Works, St. Paul, Minn.	Dec. 8, 1897
Cavanagh, John T. Quincy, Mass.	Feb. 8, 1893
Chace, George F. Supt. Water Works, Taunton, Mass.	June 13, 1888
Chadbourne, E. J. Supt. Water Co., Wakefield, Mass.	June 18, 1885
Chandler, Charles E. City Engineer, 161 Main Street, Norwich, Conn.	June 17, 1887
Chandler, Prof. Charles F. 51 East 54th Street, New York City.	Dec. 12, 1888
Chapin, G. L. Water Commissioner, Lincoln, Mass.	March 10, 1897
Chapman, Benjamin R. Asst. Engineer, Brockton, Mass.	Feb. 9, 1898
Chase, John C. Chief Engineer Water Works Co., Derry, N. H.	June 19, 1884
Clapp, Sidney K. Waterbury, Conn.	Jan. 10, 1900
Clapton, William Supt. Water Co., Newtown, N. Y.	Sept. 11, 1895
Clark, D. W. President Water Co., Portland, Me.	June 12, 1890
Clark, Frederick W. Clerk Chestnut Hill Reservoir, Metropolitan Water Works, Brighton, Mass.	Jan. 11, 1893
Clark, Harry W. Chemist, Mass. State Board of Health, State House, Boston, Mass.	March 14, 1894
Clark, S. Frederic Water Commissioner, North Billerica, Mass.	March 8, 1899
Clarke, E. W. Asst. Engineer, Rapid Transit R. R. Commission, 13 Astor Place, New York City.	Jan. 10, 1894
Cleveland, W. F. Sewer Commissioner, Brockton, Mass.	June 9, 1892
Cochran, Robert L. Supt. Water Works, Nahant, Mass.	June 16, 1886
Codd, William F. Supt. Wannacomet Water Co., Nantucket, Mass.	June 21, 1885

NAME.	Date of Election
Coffin, Freeman C. Civil and Hydraulic Engineer, 53 State Street, Boston, Mass.	Feb. 13, 1889
Coggeshall, R. C. P. Supt. Water Works, New Bedford, Mass.	June 21, 1882
Cole, D. W. Box 696, Thomaston, Conn.	March 14, 1900
Cole, F. M. Meter Inspector, Brockton Water Works, Brockton, Mass.	Feb. 10, 1897
Collins, Lewis P. Lawrence, Mass.	Dec. 12, 1894
Collins, Michael F. Supt. Water Works, Lawrence, Mass.	Sept. 18, 1901
Colson, Charles D. Water Commissioner, Holyoke, Mass.	March 9, 1898
Connell, Michael A. Supt. Water Works, St. Hyacinthe, P. Q.	Dec. 13, 1893
Cook, Byron I. Woonsocket, R. I.	March 13, 1889
Cook, Henry A. Supt. Water Works, Salem, Mass.	Feb. 10, 1892
Crandall, F. H. Supt. and Treas. Water Works, Burlington, Vt.	June 13, 1888
Crandall, George K. Civil Engineer, New London, Conn.	June 9, 1892
Crawford, J. W. Clerk of Water Board, Lowell, Mass.	June 12, 1896
Croes, J. J. R., C. E. 68 Broad Street, Morris Building, New York City.	June 17, 1887
Crosby, Everett U. 54 William Street, New York City.	March 4, 1900
Crowell, George E. President Water Works, Brattleboro, Vt.	June 15, 1893
Cuddeback, Allan W. Asst. Engineer Passaic Water Co., 109 Washington Street, Paterson, N. J.	Jan. 10, 1900
Curtis, George D. 75 Tonawanda Street, Dorchester, Mass.	Sept. 19, 1900
Cushing, Lucas Box 108, Mansfield, Mass.	Dec. 12, 1888
Daboll, L. E., C. E. New London, Conn.	Jan. 10, 1894
Danforth, John L. Gen. Supt. Spring Water Co., Kane, Pa.	Sept. 10, 1897
Davenport, Dr. B. F. Chairman Water Board, Watertown, Mass.	Feb. 14, 1900
Davis, F. A. W. Vice-Pres. and Treas. Water Co., Indianapolis, Ind.	June 17, 1887
Davis, J. M. Rutland, Vt.	Sept. 13, 1895
Davis, William E. Supt. Water Works, Sherburne, N. Y.	Dec. 11, 1889

Name.	Date of Election.
Davison, George S. Sec. and Gen. Manager Monongahela Street Railway Co., 512 Smithfield Street, Pittsburg, Pa.	June 15, 1894
Dean, Arthur W. City Engineer, Nashua, N. H.	March 8, 1899
Dean, Francis W. Mechanical Engineer, 53 State Street, Boston, Mass.	June 11, 1890
Dean, Seth, C. E. Glenwood, Iowa.	Dec. 12, 1888
Dean, William H. Water Analyst, Wilkesbarre, Pa.	Sept. 10, 1898
DeBerard, Wilford W. Spring Garden Testing Station, Philadelphia, Pa.	Sept. 19, 1900
Denman, A. N. Des Moines, Iowa.	June 16, 1886
Doane, A. O. Engineering Dept., Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	Jan. 8, 1896
Doten, Leonard S. Supt. of Construction, Quartermaster Dept. U. S. Army, 170 Summer Street, Boston, Mass.	Jan. 8, 1902
Dotten, William T. Supt. Water Works, Winchester, Mass.	June 21, 1882
Downey, Wm. 49 Wellington Street, Worcester, Mass.	June 14, 1899
Drake, Albert B., C. E. 164 William Street, New Bedford, Mass.	April 21, 1885
Drake, Charles E., C. E. New Bedford, Mass.	Jan. 8, 1890
Drown, Thomas M. President Lehigh University, So. Bethlehem, Pa.	June 13, 1888
Dunbar, E. L. Supt. Water Works, Bay City, Mich.	June 9, 1892
Dwelley, Edwin F. 144 Nahant Street, Lynn, Mass.	Sept. 18, 1901
Dyer, Eben R. Supt. of Distribution, Portland, Me.	June 11, 1890
Eardley, B. A. Supt. Pacific Improvement Co. Water Works, Pacific Grove, Monterey County, Cal.	June 15, 1893
Eddy, Harrison P. Supt. Sewer Department, City Hall, Worcester, Mass.	June 15, 1894
Eglee, Charles H. Hydraulic Engineer, 17 Central Street, Boston, Mass.	June 13, 1889
Eldredge, Edward D. Manager Onset Water Co., 49 Monmouth Street, Brookline, Mass.	Feb. 14, 1900
Ellis, George A. Civil Engineer, 158 Sherman Street, Springfield, Mass.	June 21, 1883
Ellis, John W. Civil Engineer, Woonsocket, R. I.	Dec. 11, 1889
Ellsworth, Emory A. Civil and Hydraulic Engineer, Holyoke, Mass.	June 10, 1896

NAME.	Date of Election.
Esterbrook, Arthur F. Water Commissioner, Leicester, Mass.	Sept. 10, 1897
Evans, George E. Civil Engineer, 95 Milk Street, Boston, Mass.	Feb. 14, 1888
Evans, Myron Edward Civil Engineer, 20 Nassau Street, New York City.	June 13, 1900
Ewing, William B. Civil Engineer, La Grange, Ill.	Dec. 13, 1899
Fairbank, J. H. Chairman Water Commissioners, Winchendon, Mass.	March 11, 1896
Falcon, Joseph G. Submarine Engineer, Evanston, Ill.	June 12, 1901
Fales, Frank L. Asst. Engineer, Engineering Dept., Board of Trustees, Commissioners Water Works, Cincinnati, Ohio.	Dec. 13, 1893
Fanning, John T. Consulting Engineer, Kasota Block, Minneapolis, Minn.	April 21, 1885
Farnham, Elmer E. Supt. Water Works, Box 109, Sharon, Mass.	Dec. 11, 1889
Farnum, Loring N. Civil and Hydraulic Engineer, 53 State Street, Boston, Mass.	Dec. 13, 1893
Fels, August Water Commissioner, Lowell, Mass.	Sept. 13, 1899
Felton, B. R. Civil Engineer, Tremont Building, Boston, Mass.	June 9, 1892
Felton, Charles R. City Engineer, City Hall, Brockton, Mass.	Feb. 16, 1894
Fenn, Charles W., C. E. Manager for Mechanics Falls and North Berwick Water Co., 11 Exchange Street, Portland, Me.	Sept. 18, 1901
Ferguson, John N. Asst. Engineer, Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	Dec. 14, 1898
Field, Dr. George W. Biological Dept., Massachusetts Institute of Technology, Boston, Mass.	March 13, 1901
Fisher, Edwin A. City Engineer, 16 Reynolds Street, Rochester, N. Y.	Nov. 13, 1901
Fiske, Henry A. 93 Water Street, Boston, Mass.	Sept. 18, 1901
Fitch, Jasper A. Supt. Water Co., Manchester, Conn.	June 12, 1890
FitzGerald, Desmond Engineer Sudbury Dept., Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	April 21, 1885
Flinn, Richard J., M. E. West Roxbury Station, Boston, Mass.	Sept. 11, 1895
Fobes, A. A. Engineer, Board of Public Works, Pittsfield, Mass.	Feb. 13, 1895
Folwell, A. Prescott Professor of Sanitary and Hydraulic Engineering, Lafayette College, Easton, Pa.	June 15, 1893

Name.	Date of Election.
Forbes, Fred B. 502 State House, Boston, Mass.	June 14, 1899
Forbes, F. F. Supt. Water Works, Brookline, Mass.	Jan. 29, 1885
Forbes, Murray Manager Westmoreland Water Co., Greensburgh, Pa.	Feb. 11, 1891
Foss, William E. Engineers' Dept., Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	March 8, 1893
Foster, Joel Supt. Water Works, Montpelier, Vt.	Sept. 13, 1895
Foyé, Andrew E., C. E. Acting Chief Engineer, Dept. of Highways and Viaducts, Greater New York, 11 Broadway, New York City.	Dec. 12, 1894
Freeman, John R. President Factory Insurance Co.'s, 812 Banigan Bldg., Providence, R. I.	Dec. 12, 1888
French, D. W. Supt. Hackensack Water Co., Box 98, Weehawken, N. J.	June 9, 1892
French, Edward V. Insurance Inspector, 31 Milk Street, Boston, Mass.	Sept. 10, 1897
French, Frank Baldwin Engineer and Supt. Board of Public Works, Woburn, Mass.	Sept. 16, 1898
Fteley, Alphonse 14 West 131st Street, New York City.	June 18, 1885
Fuller, Andrew D. 3 Hamilton Place, Boston, Mass.	Dec. 15, 1899
Fuller, Frank E. P. O. Box 775, West Newton, Mass.	March 14, 1900
Fuller, Frank L. Civil Engineer, 12 Pearl Street, Boston, Mass.	June 16, 1886
Fuller, George W. 100 William Street, New York City.	March 8, 1893
Gage, Stephen DeM. Biologist Mass. State Board of Health, Lawrence, Mass.	Jan. 10, 1900
Geer, Harvey M. Civil Engineer, Balston Spa, N. Y.	Sept. 10, 1897
Gerhard, William Paul Civil Engineer and Consulting Engineer for Sanitary Works, 33 Union Square, West, New York City.	Dec. 12, 1888
Gerrish, William B. Supt. and Engineer Water Works, Oberlin, Ohio.	Dec. 14, 1892
Gerry, L. L. Civil Engineer, Stoneham, Mass.	Jan. 29, 1885
Gibbs, Harry F. 106 Pond Street, Natick, Mass.	Jan. 11, 1899
Gilbert, Julius C. Water Registrar and Treas. Water Works, Whitman, Mass.	June 15, 1894
Gilderson, D. H. Supt. Water Works, Haverhill, Mass.	Sept. 11, 1895
Gleason, Fred B. Inspector, Marlboro, Mass.	Sept. 13, 1895

Name.	Date of Election.
Gleason, T. C. Supt. Water Works, Ware, Mass.	June 15, 1894
Glover, Albert S. Tremont Temple Building, Boston, Mass.	June 21, 1882
Goldthwait, W. J. Marblehead, Mass.	June 11, 1890
Goodell, Jerome W. Water Commissioner, Burlington, Vt.	Sept. 18, 1901
Goodell, John Managing Editor "Engineering Record," 100 William Street, New York City.	Sept. 18, 1901
Goodnough, X. H. Engineer State Board of Health, Room 140, State House, Boston, Mass.	Jan. 14, 1891
Gould, Amos A. Water Commissioner, Leicester, Mass.	March 11, 1896
Gould, John A. Chief Engineer, Brookline and Dorchester Gas Light Companies, 1031 Colonial Building, Boylston Street, Boston, Mass.	June 14, 1888
Gow, Frederick W. Supt. Water Works, Medford, Mass.	June 11, 1890
Gowing, E. H., C. E. 12 Pemberton Square, Boston, Mass.	April 21, 1885
Graham, James W. Supt. Meter Dept., Portland Water Co., Portland, Me.	Sept. 13, 1895
Greaney, Thomas F. Water Commissioner, Holyoke, Mass.	March 9, 1898
Greetham, H. W. Local Manager Orlando Water and Sewerage Co., Orlando, Fla.	June 13, 1889
Griffin, J. William Care N. Y. & N. J. Water Co., Arlington, N. J.	Dec. 12, 1900
Groce, William R. Supt. Water Works, Rockland, Mass.	Dec. 12, 1888
Gross, J. F. Inspector Jenkintown Water Co., Jenkintown, Pa.	June 12, 1901
Gubelman, F. J., C. E. 792 Montgomery Street, Jersey City, N. J.	March 11, 1896
Haberstroh, Charles E. Asst. Supt. Metropolitan Water Works, South Framingham, Mass.	Jan. 10, 1900
Hale, Richard A. Principal Assistant Engineer, Essex Co., Lawrence, Mass.	Feb. 14, 1888
Hall, Frank E. 32 Chestnut Street, Quincy, Mass.	June 21, 1882
Hall, Hon. John O. 1230 Hancock Street, Quincy, Mass.	Dec. 12, 1900
Hammatt, E. A. W. Civil Engineer, 53 State Street, Boston, Mass.	June 17, 1887
Hammond, J. C., Jr. Sec'y and Treas., Rockville Water and Aqueduct Co., Rockville, Conn.	Jan. 11, 1888

Name.	Date of Election.
Hancock, Joseph C. Supt. Water Works, Springfield, Mass.	June 21, 1882
Hapgood, Lyman P. Supt. Athol Water Co., Athol, Mass.	Nov. 14, 1900
Hardy, J. D. Supt. Water Works, Holyoke, Mass.	March 9, 1898
Haring, James S. Civil Engineer, Crafton, Allegheny Co., Pa.	June 9, 1892
Harlow, James H. President Pennsylvania Water Co., Wilkinsburg, Pa. Address Station D, Pittsburg, Pa.	Sept. 10, 1897
Harrington, George W. Wakefield, Mass.	Dec. 10, 1890
Harris, D. A. Supt. Water Works, New Britain, Conn.	March 14, 1888
Hart, Edward W. General Manager Water Works, Council Bluffs, Iowa.	June 10, 1891
Hartwell, David A. City Engineer, Fitchburg, Mass.	Feb. 16, 1894
Hastings, L. M. City Engineer, Cambridge, Mass.	June 13, 1889
Hastings, V. C. Supt. Water Works, Concord, N. H.	June 10, 1886
Hatch, Arthur Elliott Mechanical Engineer, Bay State Dredging Co., 59 High Street, Boston, Mass.	Dec. 11, 1895
Hatch, S. S. Water Commissioner, South Norwalk, Conn.	June 11, 1896
Hathaway, A. R. Water Registrar, Springfield, Mass.	June 10, 1891
Hawes, Louis E. Civil and Hydraulic Engineer, Tremont Building, Boston, Mass.	Dec. 12, 1888
Hawes, William B. Water Commissioner, Fall River, Mass.	June 15, 1894
Hawks, William E. Pres. and Treas. Water Co., Bennington, Vt.	Dec. 12, 1894
Hawley, W. C. Supt. Water Dept., Atlantic City, N. J.	Sept. 8, 1897
Hayes, Ansel G. Asst. Supt. Water Works, Box 323, Middleboro, Mass.	June 13, 1889
Hazard, T. G., Jr. Civil Engineer, Narragansett Pier, R. I.	June 15, 1894
Hazen, Allen Civil Engineer, 220 Broadway, New York City.	June 9, 1892
Heald, Simpson C. Civil Engineer, 48 Congress Street, Boston, Mass.	April 21, 1885
Heermans, Harry C. Supt. Water Works, Corning, N. Y.	June 16, 1886
Hering, Rudolph Hydraulic, Civil, and Sanitary Engineer, 100 William Street, New York City.	June 17, 1887

NAME.	Date of Election.
Herschel, Clemens Hydraulic Engineer, 2 Wall Street, Room 68, New York City.	Feb. 10, 1892
Hicks, R. S. 73 Warren Street, New York City.	June 17, 1887
Higgins, James H. Supt. Meter Dept., City Hall, Providence, R. I.	Feb. 8, 1893
Hill, William R. Chief Engineer Croton Aqueduct Commission, 280 Broadway, New York City.	June 9, 1892
Hodgdon, Frank W. Engineer, Mass. Harbor and Land Commission, 131 State House, Boston, Mass.	June 12, 1895
Holden, Horace G. Supt. Pennichuck Water Works, Nashua, N. H.	June 21, 1882
Hollis, Frederick S. Instructor in Chemistry, Yale Medical School, New Haven, Conn.	Dec. 8, 1897
Hook, G. S. Civil Engineer, 705 Union Street, Schenectady, N. Y.	Sept. 13, 1899
Hopkins, Charles C., C. E. Rome, N. Y.	March 10, 1897
Hotchin, George A. Supt. Water Works, Rochester, N. Y.	June 13, 1900
Howard, John L. Division Engineer, Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	Jan. 10, 1900
Hubbard, Winfred D. Supt. Water Works, Concord, Mass.	Sept. 19, 1900
Hubbell, Clarence W. Water Office, Detroit, Mich.	Sept. 13, 1899
Hughes. V. R., M. E. and E. E. 128 Willow Street, Lansing, Mich.	June 12, 1901
Hunking, Arthur W. 374 Stevens Street, Lowell, Mass.	June 11, 1890
Huntington, James A. Water Registrar, Haverhill, Mass.	Dec. 9, 1891
Jackson, Daniel D. Chemist, Division of Water Supply, Mt. Prospect Laboratory, Brooklyn, N. Y.	March 14, 1894
Jackson, William City Engineer, City Hall, Boston, Mass.	June 11, 1890
Johnson, H. R. Water Commissioner, Reading, Mass.	Dec. 14, 1898
Jones, A. J. New Brunswick, N. J.	Dec. 14, 1887
Jones, James A. Water Registrar, Stoneham, Mass.	March 14, 1894
Jordan, John N. Supt. Water Works, Malden, Mass.	June 12, 1896
Judkins, Fred G. Franklin Falls, N. H.	Feb. 14, 1899

Name.	Date of Election.
Kay, J. William Supt. Water Works, 75 Congress Street, Milford, Mass.	Jan. 9, 1901
Kent, E. W. Supt. Water Works, Woonsocket, R. I.	Feb. 8, 1893
Kent, Willard Manager Water Co., Narragansett Pier, R. I.	April 21, 1885
Kieran, Patrick Supt. Water Works, Fall River, Mass.	June 16, 1886
Kilbourn, Wm. A. Sec'y (Lancaster) Water Commissioners, South Lancaster, Mass.	Dec. 13, 1899
Killam, James W. Metropolitan Water Works, Reading, Mass.	Dec. 13, 1899
Kimball, Frank C. Supt. Knoxville Water Co., 619 South Gay Street, Knoxville, Tenn.	Feb. 12, 1896
Kimball, George A. Chief Engineer Elevated Lines, Boston Elevated Railway, 101 Milk Street, Boston, Mass.	June 17, 1887
Kingman, Horace Supt. Water Works, Brockton, Mass.	June 15, 1893
Kinnicutt, Leonard P. 77 Elm Street, Worcester, Mass.	Feb. 8, 1893
Knapp, Louis H. Engineer Buffalo Water Works, 280 Linwood Avenue, Buffalo, N. Y.	June 17, 1887
Knight, Charles William, C. E. Rome, N. Y.	March 10, 1897
Knowles, Morris Engineer Filtration Dept., Pittsburg, Pa.	June 12, 1895
Knowlton, Charles F. Commissioner of Public Works, Quincy, Mass.	Sept. 19, 1900
Koch, Harry G. Supt. Castle Creek Water Co., Aspen, Col.	Dec. 11, 1889
Kuehn, Jacob L. Supt. Water Co., York, Pa.	June 9, 1892
Kuichling, Emil Consulting Engineer, Rochester, N. Y.	Sept. 10, 1897
Laforest, J. O. Alfred Chief Engineer Laurentian Water and Power Co., La Presse Building, Montreal, Quebec.	Dec. 14, 1892
Lansing, Edward T. E. Civil Engineer, Little Falls, N. Y.	June 13, 1889
Larned, Edward S. Division Engineer Metropolitan Water Works, South Framingham, Mass.	Jan. 10, 1900
Lautz, Adolphe W. Sec'y Water Co., Pekin, Ill.	Sept. 16, 1898
Lawton, Perry Civil Engineer, Savings Bank Building, Quincy, Mass.	Feb. 16, 1894
Lea, R. S. Asst. Professor of Civil Engineering, McGill University, Montreal, P. Q.	June 15, 1893

Name.	Date of Election.
Learned, Wilbur F. Civil Engineer, Watertown, Mass.	April 21, 1885
Livermore, N. B. 320 Sansom Street, San Francisco, Cal.	Feb. 14, 1900
Locke, James W. Foreman, Brockton, Mass.	Jan. 9, 1895
Lord, Charles S. Sec'y and Manager Winooski Aqueduct Co., Winooski, Vt.	June 12, 1901
Lord, Harry A. Supt. Water Works, Ogdensburg, N. Y.	Sept. 8, 1897
Loretz, Arthur J. L. Mechanical Engineer, 150 Nassau Street, New York City.	Dec. 9, 1896
Lovell, Thomas C. Supt. Water Works, 104 River Street, Fitchburg, Mass.	June 21, 1882
Loweth, Charles F. 1100 Old Colony Building, Chicago, Ill.	Jan. 9, 1901
Luce, Francis H. Supt. Woodhaven Water Supply Co., Woodhaven, N. Y.	June 12, 1896
Ludlow, J. L. 434 Summit Street, Winston, N. C.	Feb. 14, 1900
Lunt, Cyrus M. Supt. Water Works, Lewiston, Me.	Dec. 9, 1896
Lusk, James L. Major, Corps of Engineers, U. S. A., Washington, D. C.	March 13, 1889
Luther, William J., C. E. Asst. Supt. Attleboro Gas Light Co., Attleboro, Mass.	June 15, 1893
McCarthy, Daniel B. Supt. Water Works Co., Waterford, N. Y.	Sept. 11, 1895
McClintock, W. E. Member of Massachusetts Highway Commission, 15 Court Square, Boston, Mass.	June 17, 1887
McClure, Frederick A. City Engineer, Worcester, Mass.	June 15, 1894
McConnell, B. D. Civil Engineer, 185 St. James Street, Montreal, P. Q.	June 12, 1890
McInnes, Frank A. Asst. Engineer Boston Water Works, 23 Salcombe Street, Dorchester, Mass.	Sept. 18, 1901
McIntosh, H. M. City Engineer, Burlington, Vt.	Sept. 11, 1895
McKenzie, Theodore H. Manager Water Works, Southington, Conn.	June 12, 1890
McKenzie, Thomas Supt. Water Works, Box 712, Westerly, R. I.	Dec. 12, 1894
MacLean, Thomas A. Charlottetown, P. E. I., Canada.	Jan. 8, 1902
McMillen, Norman A. Supt. Water Works, North Billerica, Mass.	June 13, 1900
MacMurray, J. C. 33 Oak Ave., Worcester, Mass.	Dec. 9, 1896

NAME.	Date of Election
Mann, Thomas W. Civil Engineer, Holyoke, Mass.	June 9, 1892
Manning, George E. Civil Engineer, New London, Conn.	March 9, 1898
Marble, Arthur D. City Engineer, Lawrence, Mass.	Feb. 12, 1896
Marion, J. A. Civil Engineer, New York Life Building, Montreal, P. Q.	Dec. 13, 1893
Martin, A. E. Supt. Water Company, South Framingham, Mass.	April 21, 1885
Martin, Cyrus B. Treas. Water Co., Norwich, N. Y.	June 17, 1887
Marvell, Edward I. Civil Engineer, 81 Bedford Street, Fall River, Mass.	Jan. 13, 1897
Mason, William P. Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y.	Dec. 11, 1895
Mather, Nelson E. Supt. Water Works, Clinton, Mass.	Sept. 19, 1900
Mattice, Asa M. Chief Engineer Westinghouse Electric and Manufacturing Co., East Pittsburg, Pa.	June 15, 1894
Maybury, William E. Supt. Water Works, Braintree, Mass.	Jan. 9, 1901
Maxcy, Josiah S. Treas. Madison Water Co., Gardiner, Me.	Dec. 14, 1887
Mead, Daniel W. Consulting Engineer, 605 First National Bank Building, Chicago, Ill.	Sept. 19, 1900
Merrill, Frank E. Water Commissioner and Supt. Water Works, Somerville, Mass.	Dec. 9, 1896
Merritt, D. S. Engineer and Supt. Water Works, Tarrytown, N. Y.	Dec. 13, 1893
Metcalf, Leonard Civil Engineer, 14 Beacon Street, Boston, Mass.	Feb. 10, 1897
Metcalfe, Henry President Water Board, Cold Spring, N. Y.	June 10, 1896
Miller, A. M. Lieut.-Col. Corps of Engineers, U. S. A., 2728 Pennsylvania Avenue, Washington, D. C.	Nov. 14, 1900
Miller, Hiram A. Clinton, Mass.	March 13, 1901
Miller, John F. Asst. Sec'y Westinghouse Air Brake Co., East Pittsburg, Pa.	June 10, 1896
Miller, P. Schuyler 108 Park Place, Brooklyn, N. Y.	Jan. 10, 1900
Mills, Frank H. City Engineer, Woonsocket, R. I.	Jan. 14, 1891
Mirick, George Langdon Civil Engineer, 104 Porter Street, Malden, Mass.	June 15, 1893

NAME.	Date of Election.
Mixer, Charles A. Resident Engineer, Rumford Falls Light and Water Co., Rumford Falls, Me.	Sept. 18, 1901
Moat, C. P. Burlington, Vt.	March 13, 1901
Molis, William Supt. Water Works Co., Muscatine, Iowa.	June 17, 1887
Moran, John W. Supt. Water Works, Gloucester, Mass.	March 13, 1901
Mullhall, John F. J. Treas. Portland (Conn.) Water Co., 11 Beacon Street, Boston, Mass.	Nov. 14, 1900
Murdoch, William Supt. Water Works, St. John, N. B.	Jan. 10, 1900
Myers, J. H., Jr. Asst. Engineer N. Y. Rapid Transit R. R. Commission, 1261 Clover Street, Bronx, New York City.	Sept. 11, 1895
Nash, George D. Supt. Winooski Aqueduct Co., Winooski, Vt.	March 13, 1901
Nash, H. A., Jr. Civil Engineer, Weymouth Heights, Mass.	March 13, 1895
Naylor, Thomas Maynard, Mass.	Feb. 16, 1894
Nettleton, Charles H. Treas. and Supt. Water Co., Birmingham, Conn.	June 16, 1886
Newhall, John B. 184 Bay Street, Stapleton, Staten Island, N. Y.	Dec. 14, 1892
Nichols, Thomas P. Member Water Board, 11 Prospect Street, Lynn, Mass.	Jan. 10, 1894
Northrop, Frank L. P. O. Box 1566, Saco, Me.	June 15, 1893
Nuebling, Emil L. Engineer and Supt. Water Dept., Reading, Pa.	Feb. 12, 1896
Nye, George H. Civil Engineer, New Bedford, Mass.	March 11, 1891
Nye, Joseph K. President Water Company, Fairhaven, Mass.	March 8, 1893
O'Connell, P. D. Supt. Water Works, Somersworth, N. H.	Sept. 16, 1898
Paine, C. W. Constructing Engineer on Extension of Butte City Water Works, Lewisohn Building, Butte, Mont.	Dec. 12, 1888
Parker, Charles B. Asst. Supt. Water Works, Cambridge, Mass.	Jan. 9, 1901
Parker, Horatio N. 456 Bloomfield Avenue, Montclair, N. J.	March 10, 1897
Parks, Charles F. Civil Engineer, 11 Beacon Street, Boston, Mass.	Dec. 11, 1889
Patch, Walter Woodbury Civil Engineer, Eastern Avenue, South Framingham, Mass.	June 12, 1895
Paulison, Washington Supt. Acquackanonk Water Co., Passaic, N. J.	Sept. 16, 1898

Name.	Date of Election.
Payson, E. R. Sec'y Portland Water Co., Portland, Me.	June 13, 1900
Pease, A. G. Water Commissioner, Spencer, Mass.	June 16, 1886
Peene, Edward L. Supt. Water Works, Yonkers, N. Y.	Sept. 16, 1898
Peirce, Charles E. Supt. East Providence Water Co., East Providence Centre, R. I.	Sept. 14, 1887
Perkins, John H. Supt. Watertown and Belmont Water Works, Watertown, Mass.	June 16, 1886
Phillips, Edward Civil Engineer, 11 Broadway, New York City.	Dec. 8, 1897
Pierce, Frank L. 464 Elm Street, Richmond Hill, Queens County, N. Y.	Dec. 14, 1898
Pitcher, Frank H. Chief Engineer Montreal Water and Power Co., 62 Imperial Building, St. James Street, Montreal, P. Q.	June 12, 1901
Pitman, Winthrop M. Treas. North Conway Water and Improvement Co. Address, 493 Centre Street, Jamaica Plain, Mass.	June 17, 1887
Pitney. Frederic V. Engineer Morristown Aqueduct Co., Morristown, N. J.	Feb. 16, 1894
Pollard, William D. General Manager Water Co., Pottsville, Pa.	June 10, 1891
Pope, Macy S. 31 Milk Street, Boston, Mass.	March 13, 1901
Porter, Dwight Professor of Hydraulic Engineering, Massachusetts Institute of Technology, Boston, Mass.	March 13, 1889
Potter, Alexander Civil and Sanitary Engineer, 137 Broadway, New York City.	March 14, 1894
Probst, C. O. Secretary State Board of Health, Columbus, Ohio.	Dec. 8, 1897
Putnam, J. B. Supt. Westboro Water and Sewer Depts., Westboro, Mass.	Sept. 10, 1897
Reynolds, E. H. Brockton, Mass.	June 9, 1892
Rice, George S. Deputy Chief Engineer, Rapid Transit Railroad Commissioners, 320 Broadway, New York City.	Dec. 14, 1892
Rice, James L. Supt. Water Co., Claremont, N. H.	June 15, 1894
Rice, L. Frederick Architect and Civil Engineer, 125 Milk Street, Boston, Mass.	June 17, 1887
Richards, Walter H. Supt. Water Works, New London, Conn.	Oct. 11, 1882
Richardson, T. F. Dept. Engineer Metropolitan Water Works, Clinton, Mass.	Feb. 10, 1897
Ridpath, J. W. Secretary and Manager Water Co., Jenkintown, Pa.	June 9, 1892

NAME.	Date of Election.
Riley, Charles E. Member Water Board, Brookline, Mass.	Sept. 13, 1899
Robbins, F. H. Civil Engineer, 1 Ashburton Place, Boston, Mass.	Sept. 10, 1897
Robertson, George H. Supt. Water Works, Yarmouth, N. S.	June 9, 1892
Robertson, W. W. Water Registrar, Fall River, Mass.	June 17, 1887
Robinson, A. Supt. Water Works, Benicia, Cal.	June 11, 1896
Roden, Thomas Supt. Water Works, Arlington, Mass.	June 12, 1896
Rogers, Thomas H. Pumping Engineer, Pennichuck Water Works, Nashua, N. H.	Sept. 8, 1897
Rotch, William Civil Engineer, Room 742, Exchange Building, 53 State Street, Boston, Mass.	June 16, 1886
Roullier, G. A. Supt. Water Works, Flushing, N. Y.	June 13, 1889
Royce, Harley E. Asst. Engineer, Brookline, Mass.	Jan. 9, 1895
Russell, A. N. President Water Commissioners, Illion, N. Y.	Sept. 13, 1899
Sando, W. J. Manager Water Works Dept., International Steam Pump Co., Brooklyn, N. Y.	June 12, 1895
Saville, Caleb M. Engineering Dept., Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	March 8, 1893
Scott, Walter M. Resident Engineer Chatham Water Works and Sewerage System, Chatham, N. B.	Nov. 13, 1901
Sears, Walter H. 220 Sandwich Street, Plymouth, Mass.	Sept. 13, 1899
Sealy, W. F. P. Supt. Water Works, Potsdam, N. Y.	Sept. 13, 1895
Sedgwick, William T. Professor of Biology, Massachusetts Institute of Technology, Boston, Mass.	Feb. 12, 1890
Sharples, Philip P. 22 Concord Avenue, Cambridge, Mass.	June 14, 1899
Shedd, Edward M. Inspector Water Works, Somerville, Mass.	Jan. 9, 1901
Shedd. Edward W. Civil Engineer, 146 Westminster Street, Providence, R. I.	March 9, 1892
Shedd, J. Herbert Consulting Engineer, Providence, R. I.	June 13, 1888
Sherman, Charles W. Civil Engineer, Assistant Engineer Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	Sept. 10, 1897
Sherman, William B. Mechanical Engineer, Box 974, Providence, R. I.	Oct. 11, 1882

Name.	Date of Election.
Sherrerd, Morris R. Engineer Water Dept., Newark, N. J.	March 10, 1897
Shippee, John D. Holliston, Mass.	Jan. 14, 1891
Shirreffs, Reuben Chief Engineer Virginia Electric Railway and Development Co., Richmond, Va.	March 12, 1890
Sinclair, Melville A. Supt. Water Works, Bangor, Me.	June 15, 1894
Smith, Herbert E. Professor of Chemistry, Yale Medical School; Chemist Connecticut State Board of Health. Address, 430 George Street, New Haven, Conn.	Dec. 14, 1892
Smith, H. O. Water Commissioner, Leicester, Mass.	June 15, 1894
Smith, John E. Supt. Water Works, Andover, Mass.	June 10, 1896
Smith, J. J. City Engineer, Grand Forks, N. D.	Nov. 14, 1900
Smith, J. Waldo Supt. Passaic Water Co., 109 Washington Street, Paterson, N. J.	Dec. 13, 1893
Smith, Sidney Civil Engineer, 91 Maple Street, West Roxbury, Mass.	June 12, 1895
Smith, Solon F. Supt. and Treas. Water Co., Grafton, Mass.	June 17, 1887
Snell, George H. Water Commissioner and Supt. Water Works, Attleboro, Mass.	Dec. 12, 1900
Soper, George A. 29 Broadway, New York City.	Jan. 12, 1898
Souther, Henry Water Commissioner, Hartford, Conn.	June 13, 1900
Sparks, H. T. Supt. Water Dept., Public Works Co., Bangor, Me. Address, Box 208, Brewer, Me.	June 15, 1894
Spooner, Herman W. Engineer Gloucester Water Works, 28 Granite Street, Gloucester, Mass.	Nov. 13, 1901
Sprenkel, John F. General Manager York Water Co., York, Pa.	June 12, 1901
Springfield, John F. Civil Engineer, 64 Summer Street, Rochester, N. H.	Jan. 13, 1892
Stacy, George A. Supt. Water Works, Marlboro, Mass.	April 21, 1885
Stearns, Frederic P. Chief Engineer Metropolitan Water and Sewerage Board, 1 Ashburton Place, Boston, Mass.	June 17, 1887
Stevens, James T. Chairman Board of Water Commissioners, South Braintree, Mass.	Jan. 8, 1902
Stevenson, Harry W. Nadine, Allegheny Co., Pa.	Sept. 21, 1900

NAME.	Date of Election.
St. Louis, J. A. Water Registrar, Marlboro, Mass.	Sept. 10, 1897
Stone, Dr. B. H. Burlington, Vt.	March 13, 1901
Stone, Charles A. Electrical Engineer, 93 Federal Street, Boston, Mass.	June 15, 1894
Street, L. Lee 27 Pearl Street, Dorchester, Mass.	Jan. 10, 1900
Sullivan, John C. Holyoke, Mass.	June 15, 1893
Sullivan, J. J. Water Commissioner, Holyoke, Mass.	March 9, 1898
Sullivan, William F. City Engineer's office, Lowell, Mass.	Feb. 14, 1900
Swain, George F. Professor of Civil Engineering, Massachusetts Institute of Technology, Boston, Mass.	June 17, 1887
Swan, Joseph W. Asst. Clerk, Water Commissioner's office, Boston, Mass.	Feb. 11, 1891
Taber, Robert W. Water Commissioner, New Bedford, Mass.	Sept. 16, 1898
Taylor, Charles N. Contracting Engineer, Wellesley, Mass.	Feb. 13, 1901
Taylor, Edwin A. Constructing Engineer, 73 Tremont Street, Boston, Mass.	Dec. 14, 1892
Taylor, Frederick L. Engineer, Brookline Water Works, Brookline, Mass.	Feb. 13, 1895
Taylor, Lucian A. Civil Engineer and Contractor, 73 Tremont Street, Boston, Mass.	June 19, 1884
Tenney, D. W. Methuen, Mass.	June 10, 1896
Tenney, Joseph G. Treas. and Supt. Water Works, Leominster, Mass.	June 21, 1882
Thomas, Robert J. Supt. Water Works, Lowell, Mass.	June 9, 1892
Thomas, Harry L. Asst. Supt. Water Co., Hingham, Mass.	Dec. 14, 1898
Thomas, William H. Supt. Water Co., Hingham, Mass.	Dec. 14, 1887
Thomson, John Hydraulic Engineer, 253 Broadway, New York City.	June 9, 1892
Tighe, James L. Engineer Water Works, Holyoke, Mass.	March 9, 1898
Tingley, R. H. Civil Engineer, 75 Westminster Street, Providence, R. I.	Feb. 8, 1893
Tinkham, S. Everett Asst. Engineer, Engineering Dept., City Hall, Boston, Mass.	Jan. 14, 1891
Tompkins, Charles H. Civil Engineer, 120 Liberty Street, New York City.	Dec. 11, 1889

Name.	Date of Election.
Tower, D. N. Supt. Water Co., Cohasset, Mass.	June 17, 1887
Travis, George W. Supt. Water Works, Natick, Mass.	Dec. 13, 1899
Treman, E. M. Supt. and Sec'y, Water Co., Ithaca, N. Y.	June 11, 1890
Tribus, Louis L. Consulting Civil and Hydraulic Engineer, 84 Warren Street, New York City.	March 11, 1896
Tubbs, J. Nelson General Inspector, Dept. of Public Works, State of New York, 207 Wilder Building, Rochester, N. Y.	June 11, 1890
Turner, H. N. Manager Water Co., St. Johnsbury, Vt.	Dec. 11, 1895
Tuttle, Arthur S. Civil Engineer, Department Water Supply, 82d Street, near 11th Avenue, Brooklyn, N. Y.	March 14, 1894
Vallaincourt, J. A. Asst. Treas. Water Co., Berlin, N. H.	Sept. 13, 1899
Vaughn, W. H. Supt. Water Works, Wellesley Hills, Mass.	Dec. 11, 1889
Venner, John Chief Inspector Bureau of Water, Syracuse, N. Y.	Jan. 11, 1899
Wade, William W. Water Registrar, Woburn, Mass.	Dec. 8, 1897
Walker, Charles K. Supt. Water Works, Manchester, N. H.	June 21, 1882
Walker, John Civil Engineer, Newmarket, N. H.	Dec. 12, 1894
Wallace, E. L. Supt. Water Works, Franklin Falls, N. H.	Dec. 14, 1892
Warde, Charles S. Cashier Staten Island Water Supply Co., West New Brighton, Staten Island, N. Y.	Sept. 18, 1901
Warde, John S. Supt. Staten Island Water Supply Co., West New Brighton, Staten Island, N. Y.	June 15, 1894
Warren, H. A. Supt. Water Works, St. Albans, Vt.	Dec. 14, 1892
Webster, F. P. Supt. Water Works Co., Lakeport, N. H.	Jan. 8, 1890
Wegmann, E. Division Engineer on construction of new Croton Reservoirs, Katonah, N. Y.	June 12, 1901
Wescott, George P. Treas. Portland Water Co., Portland, Me.	June 16, 1886
West, George F. Manager Water Works, Union Mutual Building, Portland, Me.	Nov. 13, 1901
Weston, Robert S. Chemist and Bacteriologist, 14 Beacon Street, Boston, Mass.	Sept. 8, 1897
Wheeler, Elbert Treas. Water Co., 14 Beacon Street, Boston, Mass.	Dec. 9, 1891

Name.	Date of Election.
Wheeler, William Civil Engineer, 14 Beacon Street, Boston, Mass.	Dec. 11, 1889
Whipple, George C. Mt. Prospect Laboratory, Flatbush Avenue and Eastern Parkway, Brooklyn, N. Y.	Feb. 8, 1893
Whitcomb, W. H. President Water Co., Norway, Me.	June 16, 1886
Whitham, Jay M. Mechanical Engineer, 607 Bullitt Building, Philadelphia, Pa.	Dec. 13, 1893
Whitman, Herbert T. Civil Engineer, 85 Devonshire Street, Boston, Mass.	Feb. 8, 1893
Whitney, John C. Water Commissioner, Newton, Mass.	June 17, 1887
Whittemore, W. P. Supt. Electric Light and Water Depts., North Attleboro, Mass.	June 16, 1886
Wigal, James P. Henderson, Ky.	June 16, 1886
Wilde, George E. Asst. Supt. Metropolitan Water Works, Medford, Mass.	June 16, 1886
Wilder, Frederick W. Treas. Aqueduct Co., Woodstock, Vt.	Dec. 12, 1888
Wilkins, Frank B. Supt. Water Works, Milford, N. H.	Feb. 14, 1900
Williams, Gardner S. Engineer in charge of Hydraulic Laboratory, and Professor of Experimental Hydraulics, Cornell University, Ithaca, N. Y.	June 12, 1895
Williams, William F. City Engineer, New Bedford, Mass.	Feb. 16, 1894
Winslow, C.-E. A. Massachusetts Institute of Technology, Boston, Mass.	Sept. 21, 1900
Winslow, Frederic I. Asst. Engineer, City Engineer's office, City Hall, Boston, Mass.	Jan. 13, 1892
Winslow, George E. Waltham, Mass.	June 18, 1885
Winslow, S. J. Supt. Water Co., Pittsfield, N. H.	June 17, 1887
Wiswall, E. T. West Newton, Mass.	June 13, 1889
Wood, Henry B. Harbor and Land Commission, State House, Boston, Mass.	Dec. 13, 1893
Woodruff, Timothy Supt. Water Works, Bridgeton, N. J.	June 13, 1888
Woods, Henry D. West Newton, Mass.	Jan. 9, 1895
Woods, L. R. Supt. Water Dept., 206 Vine Street, Everett, Mass.	Sept. 18, 1901
Worthington, E., Jr. Civil Engineer, Dedham, Mass.	Jan. 11, 1893
Wright, George W. Chief Engineer, Water Dept., Box 426, Norfolk, Va.	June 9, 1892

Name.	Date of Election.
Yorston, W. G. Constructing Engineer, Box 470, Truro, N. S.	Dec. 14, 1892
Youngren, Carl J. Boston Water Dept., City Hall, Boston, Mass.	Dec. 13, 1899
Zick, W. G. 253 Broadway, New York City.	June 15, 1893

Honorary Members.

Frost, George H. President Engineering News Pub. Co., St. Paul Building, New York City.	June 16, 1886
Gale, James M. Engineer-in-Chief Loch Katrine Water Works, Glasgow, Scotland.	Jan. 16, 1889
Meyer, Henry C. The Engineering Record, 100 William Street, New York City.	June 17, 1887
Shepperd, F. W. "Fire and Water," Bennett Building, Nassau and Fulton streets, New York City.	Feb. 12, 1890

Associates.

Allis-Chalmers Co. "High Duty Pumping Engines," Milwaukee, Wis.	Dec. 13, 1893
Ashton Valve Co. "Water Relief Valves," 271 Franklin Street, Boston, Mass.	June 18, 1885
Barr Pumping Engine Co. Philadelphia, Pa.	Feb. 13, 1901
Harold L. Bond & Co. "Construction Work Supplies," 140 Pearl Street, Boston, Mass.	Dec. 12, 1900
Brandt, Randolph "Selden Patent Packing," 38 Cortlandt Street, New York City.	April 21, 1885
Brewster, H. M. (E. Stebbens Mfg. Co.) "Brass Goods," Brightwood P. O., Springfield, Mass.	June 13, 1888
Builders Iron Foundry P. O. Box 218, Providence, R. I.	June 17, 1887
J. B. Campbell Brass Works 16th and Cascade streets, Erie, Pa.	Sept. 18, 1901
Chadwick-Boston Lead Co. 162 Congress and 180–182 Franklin streets, Boston, Mass.	April 21, 1885
Chapman Valve Mfg. Co. "Valves and Hydrants," Indian Orchard, Mass.	June 21, 1883
Charles A. Claflin & Co. "Steam Engineering and Water Works Supplies," 188 Franklin Street, Boston, Mass.	Jan. 9, 1901
Coffin Valve Co. "Valves and Hydrants," Neponset, Boston, Mass.	June 16, 1886
Deane Steam Pump Co. "Steam Pumps and Pumping Machinery," Holyoke, Mass.	April 21, 1885
Dibble, F. J. "Electric Gages," Peabody, Mass.	June 11, 1890

Name.	Date of Election.
Drummond, M. J. "Cast Iron Pipe," 192 Broadway, Corbin Building, New York City.	Dec. 14, 1887
Dunne, George C. Manager Portland Stoneware Co., 42 Oliver Street, Boston, Mass.	Feb. 10, 1892
Eagle Oil and Supply Co. 104 Broad Street, Boston, Mass.	June 15, 1894
Garlock Packing Co. "Packing," 12 Pearl Street, Boston, Mass.	June 11, 1896
William H. Gallison Co. "Engineer's Supplies, Pipe, etc.," 36 Oliver Street, Boston, Mass.	June 18, 1885
Gilchrist, George E. "Pipes and Fittings," 106 High Street, corner Congress Street, Boston, Mass.	Jan. 11, 1888
The Goulds Mfg. Co. "Engines," 236 Congress Street, Boston, Mass.	Sept. 11, 1895
Hersey Mfg. Co. "Meters," South Boston, Mass.	June 16, 1886
International Steam Pump Co. P. O. Box 14, Brooklyn, N. Y.	June 12, 1901
Jenks, Henry F. "Drinking Fountains," Pawtucket, R. I.	April 21, 1885
Kennedy Valve Co. "Valves, Hydrants, and Indicating Devices," 57 Beekman and 87 Ann streets, New York City.	Sept. 8, 1897
Lamb & Ritchie "Tin-lined Iron Pipe and Lead-lined Iron Pipe," Cambridge, Mass.	Dec. 12, 1900
Lead Lined Iron Pipe Co. "Lead and Tin Lined Pipe," Wakefield, Mass.	Sept. 8, 1897
Libbey, Parker & Co. "Plumbing, Steam, Water Works Specialties and Supplies," 416 Atlantic Avenue, Boston, Mass.	March 14, 1900
Ludlow Valve Mfg. Co. "Valves and Hydrants," 150 High Street, Boston, Mass.	June 18, 1885
Lynch, John E. Proprietor "E. Hodge & Co., Stand Pipes," East Boston, Mass.	June 10, 1891
Montreal Pipe Foundry Co., Lt'd Acadia Mines, Londonderry, N. S.	Jan. 8, 1902
Moore, Charles A. "Engines, Boilers, and Supplies," 85 Liberty Street, New York City.	Dec. 9, 1896
I. P. Morris Co. "Pumping Engines and Turbines," corner Beach and Ball streets, Philadelphia, Pa.	June 15, 1894
H. Mueller Mfg. Co. "Water Works Supplies," Decatur, Ill.	Sept. 11, 1895
National Lead Co. (Boston Branch) 89 State Street, Boston, Mass.	March 14, 1894

NAME.	Date of Election.
National Meter Co.	Oct. 11, 1882
"Meters," 84 Chambers Street, New York City.	
National Tube Co.	April 21, 1885
"Pipe and Fittings," McKeesport, Pa. Address, 95 Milk Street, Boston, Mass.	
Neptune Meter Co.	June 15, 1893
"Trident Water Meters," Jackson Avenue and Crane Street, Long Island City, N. Y.	
New York Continental Jewell Filtration Co.	June 15, 1894
"Filters," 15 Broad Street, New York City.	
Norwood Engineering Co.	April 21, 1885
"Hydrants, Filters, etc." Florence, Mass.	
Peck Bros. & Co.	Dec. 12, 1894
"Water Works Supplies," 65 Oliver Street, Boston, Mass.	
Perrin, Seamans & Co.	June 11, 1890
"Construction Tools and Supplies," 57 Oliver Street, Boston, Mass.	
Pittsburg Meter Co.	June 15, 1894
"Water Meters," East Pittsburg, Pa.	
Rensselaer Mfg. Co.	June 11, 1890
"Valves and Water Gates, and Sole Manufacturers of Corey Fire Hydrant," Troy, N. Y.	
Roberts, C. E.	March 13, 1889
Hartford Steam Boiler Inspection and Insurance Co., 125 Milk Street, Telephone Building, Boston, Mass.	
Robinson, Edward	Dec. 13, 1899
"Wells Light Mfg. Co.," 44–46 Washington Street, New York City.	
Ross Valve Co.	June 13, 1888
"Valves," Troy, N. Y.	
Sampson, George H.	June 18, 1885
"Powder," 13 Pearl Street, Boston, Mass.	
A. P. Smith Mfg. Co.	Feb. 10, 1892
"Tapping Machines," Passaic Avenue, foot of Brill Street, Newark, N. J.	
B. F. Smith & Bro.	Sept. 10, 1897
"Artesian and Driven Wells," 38 Oliver Street, Boston, Mass.	
Sumner & Goodwin Co.	April 21, 1885
"Water Works Supplies," 287 Congress Street, Boston, Mass.	
Sweet & Doyle	June 13, 1900
Selling Agents Vincent Valves, Cohoes, N. Y.	
Thomson Meter Co.	June 13, 1888
"Water Meters," 79 Washington Street, Brooklyn, N. Y.	
Union Water Meter Co.	June 21, 1883
"Water Meters," 31 Hermon Street, Worcester, Mass.	
United States Cast Iron Pipe and Foundry Co.	Sept. 13, 1899
Corner Broad and Chestnut streets, Philadelphia, Pa.	
Waldo Bros.	April 21, 1885
"Contractors' Supplies," 102 Milk Street, Boston, Mass.	
Walworth Mfg. Co.	April 21, 1885
"Pipe, Brass Work, Service Boxes, etc.," 134 Federal Street, Boston, Mass.	

Name.	Date of Election.
R. D. Wood & Co. "Cast Iron Pipe," 400 Chestnut Street, Philadelphia, Pa.	June 19, 1884
The George Woodman Co. "Pipe and Fittings," 41 Pearl Street, Boston, Mass. P. O. Box 3653.	April 21, 1885

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THE DRAINAGE OF SWAMPS FOR WATERSHED IMPROVEMENT.

BY EDWARD S. LARNED, DIVISION ENGINEER, METROPOLITAN WATER WORKS, SOUTH FRAMINGHAM, MASS.

[*Presented December 11, 1901.*]

In the development of the water supply of Boston and the Metropolitan District, the aim has been to provide not only an abundant supply, but a quality of water wholesome and attractive in appearance and taste. Great care and much expense have been devoted to the preparation of storage reservoir sites, in the removal of soil and organic matter, providing against shallow flowage, and keeping the watersheds free from contamination by sewage or other waste products of human life and industry.

The quality and appearance of all surface waters, such as ponds, lakes, rivers, and brooks, are affected by the physical characteristics of the areas drained, and when a watershed contains many swamps, it is known that the effluent streams will contain a large amount of dissolved organic matter, giving the water a deep color and furnishing food products for organisms that under certain conditions will impart a most unpleasant odor and taste to the water in the storage reservoirs.

While it is generally supposed that water unpleasant to the sight, taste, and smell from such causes is innocuous, we have it on good medical authority that it superinduces bowel complaints, zymotic troubles, dysentery, and low fevers.

In the case of an unpolluted dark surface water, the color is generally indicative of the amount and condition of the organic matter present, and any improvement tending to reduce the color will prove of value not alone from the æsthetic view, improving the appearance of the water, but, by a corresponding reduction in the supply of nitrogenous food for animal and vegetable organisms, tends to remove one of the most important factors in producing bad tastes and odors in the water of storage reservoirs.

In a large reservoir suitably prepared by the removal of all soil and vegetable matter, a marked reduction of color will be noted in

water not changed oftener than once in eight months, and if allowed to remain in storage for a year or more, it will become practically colorless. This fact is established under the investigations of the Massachusetts State Board of Health, and a very instructive discussion of the subject is found in the special report of this board, on Examinations of Water Supplies, for the year 1890, by Dr. Thomas M. Drown, chemist of the board.

Ideal conditions of storage and watershed are seldom attainable, and it follows that the purer a water can be delivered to the storage reservoir, assuming the latter to be properly cleaned out, the less the chance of deterioration and the more wholesome and acceptable it will be to the consumer.

SWAMP DRAINS.

In the Sudbury watershed the many swamps existing along the brooks tributary to Framingham Reservoir No. 3, the new Sudbury Reservoir, and the open channel at the lower end of the Wachusett Aqueduct, which flows into the Sudbury Reservoir, made it seem expedient to construct a system of ditches to intercept or facilitate the passage of water from the uplands through or around the swamps. The latter are generally very nearly level, without well-defined water courses, and such as are found are badly congested with rank vegetation and rotting wood; soundings find the mud or peat deposit from one foot to more than thirty feet in depth. Most of the swamps are timbered, the growth being maple, pine, alder, birch, chestnut, elm, dogwood, and cedar, with often a rank undergrowth, and it is to be expected that water held in check or passing slowly through such a place would acquire a high color. Figs. 1 and 2, Plate I, show conditions characteristic of the swamps.

In order to properly locate and determine the capacity of the ditch required, a survey is made showing the outlines of the swamp; soundings and surface elevations are taken from the edge of the swamp out to a point beyond the probable location of the ditch, with an occasional cross section over the full width of the swamp; influent brooks are noted; the limits of timber and open land located; property lines taken, and a reconnoisance of the limits of the watershed above the point of the proposed improvement is made. A paper or plan location is made, the line run out on the ground and adjusted, if necessary, to escape bowlders or other difficulties not indicated in the preliminary survey.

When the swamp is long and narrow, a single ditch suffices, located on the side from which the larger yield is received; the influent brooks, if any, on the opposite side of the swamp are to be led by cross drains into the main ditch.

In the case of a more extensive swamp, the drains are constructed on the edge surrounding it, thus intercepting the entire upland yield, and carrying the water by, before it comes in contact with any part of the swamp; and with the bottom of the ditches usually below the peat formation, in sand or gravel, it follows that more or less ground water is also cut off from the swamp, and the latter soon becomes moderately dry and capable of producing a good quality of grass if cultivated; this further improvement is encouraged among the land owners, particularly in the case of abandoned or neglected meadows, and the opportunity thus afforded by adequate drainage to reclaim land has been an important factor in securing ditching rights through private land without payment therefor. In this connection it may be stated that all of the improvement effected under supervision of the writer was through private land; 47 411 feet of improved ditches were constructed, passing through or affecting twenty-seven separate estates, and the necessary rights were secured at a total expenditure for damages, real or fancied, of $49.82.

In negotiating with the land owner, the nature and extent of the proposed improvement were explained in detail; the benefits to be derived by both parties to the agreement pointed out; ample time for consideration was given, and oftentimes several interviews were necessary; it is not uncommon to find men loth to grant any privilege to a municipality or commonwealth without a money consideration, though they suffer no loss or damage and even derive a benefit thereby. Upon securing consent, the following simple form was filled out and signed: —

I, (John Brown,) of Southboro, Mass., hereby consent that the Metropolitan Water Board may, without charge, dig and maintain channels for the drainage of my low land in Southboro, substantially on lines shown on a plan hereto annexed, entitled, "DRAINAGE OF SWAMPS," "ANGELICO BROOK," dated May, 1900.

The earth removed from such new channels shall be neatly leveled off or used in filling the channels of existing brooks wherever I may permit such filling.

(Four) (4) bridges shall be built in a substantial manner across said channels at points to be designated by me.

FIG. 1. — WOODED SWAMP.

FIG. 2. — OUTLET OF SWAMP IN BOWLDER GROUND.

(Two) (2) watering places shall be provided at points to be designated by me.

Said board shall have the right to cut and remove all wood and timber on land owned by me within twenty feet from the center and on each side of said drain, and agrees as part consideration for this agreement to haul to hard land and cord up all wood cut on said lands under the provisions of this agreement, or shall leave the same in the log if so directed.

In consideration of the benefits to be derived by me from the foregoing arrangement, I agree without further consideration, etc.

(Signed) JOHN BROWN.

MAY 15, 1900.

Some were found willing to promote the improvement in every way; individual effort to drain land was not uncommon, but usually ineffectual through want of combined action on the part of adjacent owners, poor construction and maintenance.

The drain constructed by the Metropolitan Water Works, a cross section of which is shown in Fig. 1, is designed to carry three quarters of an inch of rainfall collected in twenty-four hours, at a velocity not to exceed two feet per second; this capacity is deemed sufficient except at times of extreme high flow, too infrequent to warrant special provision therefor.

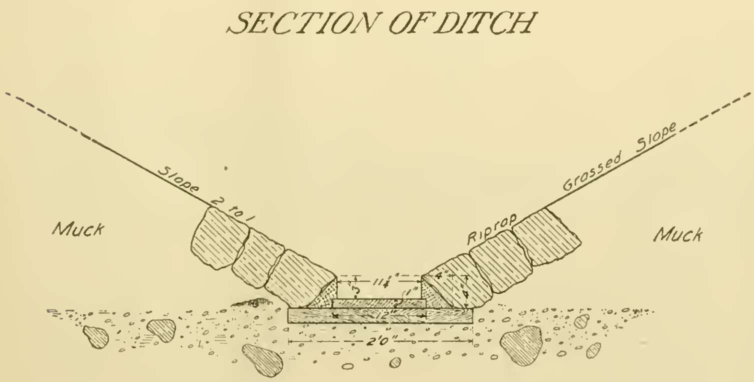

FIG. 1.

The drain has a board bottom, twelve inches wide, upper side planed, resting on mud-sills 2″ x 4″ x 2′, spaced about three feet apart and set flush with the ground; on either side are wood strips made of 4″ x 4″ stock, sawed on the diagonal and rabbeted to set

over the edge of the board about three eighths of an inch, serving as a footing for the stone paving on the sides of the channel, and to hold the boards in place when the nails used may give out through the action of rust.

The side slopes, two horizontal to one vertical, are protected by paving from six to nine inches thick, up to a point above the normal surface of the water; at all turns and connecting ditches the exposed slopes are protected by paving for the full height; paved gutters are made for influent streams coming in from the side. Fig. 1, Plate II, shows the clearing made through woodland, and Fig. 2 shows character of riprap placed, also including platform bridge placed at a farm-road crossing.

It will appear that straight line construction is necessary; but all deflections over thirty degrees are eased off by several short panels. In timber, sprout, or brush land, a clearing forty feet wide is made; this serves to keep falling leaves out of the ditch and during construction offers an opportunity for teams hauling lumber and stone to deliver material close by the work; the tree-tops, small brush, and swamp grass were often used to support the wagons over soft ground, and frequently both stone and lumber had to be carried in to the work from the nearest accessible point on hard land. Lumber was obtained in carload lots, and the haul from nearest railroad station averaged from one to three miles. All stones found in the excavations were used for paving, but were a small part of the amount required; the farmers donated many old walls; pasture lots furnished some by grubbing; and in some instances stones were purchased at ten cents per load and the farmers employed to haul them; this, however, was only done as a means to secure the ditching rights.

The depth of the ditches averages two feet, and varies between one and one-half and three feet. The excavated material was used to fill up all old brook courses and low places near by; any surplus was spread thin on the swamp side of the ditch and gaps left in the filling at frequent intervals and at all low places, to freely admit water into the ditch at times of freshet. For the convenience of the land owner, culverts or bridges over the drain are built at farm-road crossings and other points where necessary; watering places provided for grazing stock by depressing the bottom of the ditch from eight to twelve inches for the length of one board (usually sixteen feet), and taking out one or both sides of the ditch to a flat slope, and pro-

FIG. 1.—SHOWING CLEARING MADE IN WOODED SWAMP.

FIG. 2.—SHOWING RIPRAP PROTECTION AT CONNECTING DITCHES.

tecting the bottom with paving or gravel; the trough being in line with the ditch provides for free circulation and avoids the tendency to stagnation, which exists if placed on the side.

To explain method of construction: the clearing is made well in advance of excavation, and stumps found within the lines of the ditch are removed; a trench three feet wide, with vertical sides, is dug to within a few inches of grade; line and grade stakes are then driven in the trench every twenty-five feet, one foot off center and with a nail in the side one foot above sill grade; one man undercuts the sides to admit the paving, working to the line; another man or two remove the few inches of material remaining to grade; two men follow with spirit level, mattock, and rammer, setting the sills; two men in turn place the boards to line, nail to sills, and spike on the side strips; then come a gang of pavers, followed by a gang trimming slopes and grading.

The success, from the point of expense, of the work depends upon one operation following the other immediately; pumping is an expensive item, and one operation must be made to serve the board laying, paving, and sloping.

A succession of swamps, large and small, may often be found along the course of a brook, with various stretches of swiftly flowing water between; of course in this case the ditches are not made continuous, but sufficient work is done in the original brook bed to lead the water directly into the drain, and to secure a good run-off at the lower end; in this way, in connection with the 47 411 feet of improved ditch, 2 500 feet of the original brook courses were cleaned out and deepened.

Experience as usual proved a good teacher, and the work of the second season was accomplished at a lower cost than that of the first.

The work of swamp drainage was begun in 1898 by the Dam and Aqueduct Department; to the end of 1900 this department constructed 82 099 feet of ditches in the Sudbury watershed in connection with swamps draining into the open channel of the Wachusett Aqueduct, and 15 048 feet of ditches in the Wachusett watershed. The Sudbury department began work in 1899 and completed the improvement on five brooks tributary to the Sudbury Reservoir and Framingham Reservoir No. 3 during the following year.

The following table shows the cost of all the swamp drains constructed by the Sudbury department, exclusive of engineering: —

Location.	Timbered Ditch (Feet).	Total Cost.	Cost per Foot.
Angelico Brook	9 702	$3 904.83	$0.402
Brewer Brook	5 500	1 343.59	.244
Deerfoot Brook	7 876	2 449.61	.311
Mowry and Broad Meadow Brooks	24 333	5 717.76	.235
Total	47 411	$13 415.79	
Average			$0.283

The work was done by day labor, receiving $1.50 for nine hours' work; a few men were paid from $1.80 to $2.00 per day.

During 1900 a careful cost account was kept for the 24 333 feet of ditches on the Mowry and Broad Meadow Brook Improvement, as follows: —

LABOR COST ONLY.

Period. Sept. 1 to Dec. 8	Excavation and Clearing.	Timber Bottom.	Riprap and Stone Deliv.	Drilling and Blasting.	Culverts and Bridges.
Average cost per foot	0.093	0.024	0.052	0.004	0.006

Total average labor cost per lineal foot of ditch	$0.179
Lumber, hardware, blasting supplies, etc.	.056
Total average cost per foot	$0.235

STATEMENT OF WORK.

Length of drain through woodland, 13 410 feet.
Length of drain through meadowland, 10 923 feet.
9 stone culverts (average 2.8 x 2.6), 109 feet.
21 timber bridges, chestnut stringers, 2″ plank floor, average 8′ x 10′.
10 watering places.
2″ x 4″ spruce, average cost $13.50 per M, 16 535 feet B. M. used.
4″ x 4″ spruce (side rails) average cost $15.93 per M, 32 582 feet B. M. used.
1″ x 12″ spruce and Pennsylvania hemlock, average cost $17.11 per M, 25 171 feet B. M. used.

NOTE. —Lumber cost f. o. b. cars delivered.
Average cost of lumber per foot of ditch, $0.048.

It remains to be shown what improvement in color of water has been observed.

Since the construction of the ditches, color observations have been taken once each month, about the 15th, at a given point near the reservoir into which the brook flows. Prior to the improvement, color determinations had been made from the same points in the same way for a period covering at least one year, and in most instances a longer time.

The following table, prepared under the direction of Mr. Desmond FitzGerald, engineer of the Sudbury department, is intended to show the improvement up to May 15, 1901 : —

SUMMARY OF NORMAL COLORS AND REDUCTION OF COLORS BY DITCHING.

	Normal Color before Ditching.	Normal Color after Ditching.	Difference.	Reduction of Color, Per Cent.
Brewer Brook	0.70	0.58	0.12	17
Angelico Brook	1.15	0.79	0.36	31
Deerfoot Brook	1.27	0.90	0.37	29
Choate Brook	1.15	0.60	0.55	48
Outlet of Crane Swamp	1.81	1.08	0.73	40
Brigham's Pond Brook	0.81	0.59	0.22	27
Mowry Brook	0.63	0.48	0.15	24
Broad Meadow Brook	0.59	0.51	0.08	14
Average				29

Normal colors have been computed from observed colors by multiplying each observation by the yield of the Sudbury watershed for the month during which the observation was made, and dividing the sum of the products by the sum of the yields (multipliers).

It is known that local conditions may seriously affect the result of one observation, and it would appear desirable to have the observations made oftener than once a month or extended over a longer period before predicating results, but it seems conservative to expect a reduction of color of at least thirty per cent. from swamp drainage, and in aggravated cases it would probably be much greater.

In the above table the differences in the reduction of color are accounted for in the ratio of swamp area to total drainage area, the location of the swamp with reference to the outlet of the brook and the point at which color determinations are made. It is apparent that a greater reduction of color would follow when ninety per cent. of the entire yield passed through a swamp, than in a case where only twenty-five per cent. came in contact with the swamp.

The writer is of the opinion that with the maintenance of these drains and the gradual reclamation of swampy meadows by the land owners, which is reasonably sure to follow, and is even now in progress, the greatest improvement is yet to come.

It may be only a coincidence, but in the case of the Choate Brook, which shows the greatest improvement in color of any of the

brooks treated, a large, swampy meadow contiguous to the drain was immediately reclaimed by the owner and converted into a fine grass-producing meadow. Figs. 1 and 2, Plate III, show characteristic conditions observed before and after drainage.

DISCUSSION.

The Chairman. With the exception of those cities and towns which depend entirely on driven well supplies, I suppose there is hardly a place which is not troubled at times with either a discoloration or a bad taste in the water. The subject is open for discussion.

Mr. Horatio N. Parker.* Mr. Larned has pointed out that the drainage of the swamps is a very effective method of preventing the growth of microscopic organisms. I should like to emphasize this and recommend the speaker's treatment to the members as a means of reducing the evils from this source in their reservoirs. These swamp waters usually contain a large amount of carbonic acid, which recent experiments † have shown to be one of the chief food materials of the microscopic organisms; so when these waters come into a reservoir they not only may bring large growths but they are likely to stimulate the development of forms already living there. The two last pictures are very instructive. The swamp as we saw it in Fig. 1, Plate III, with its half-submerged vegetation and quiet water, was an ideal place for plankton development. A heavy rain will wash the organisms out of the swamp into the storage reservoir, where they are likely to grow and make the water unfit for drinking, on account of the unpleasant taste and odor which they produce. The second picture shows this danger entirely removed. Undoubtedly there are many supplies in the care of the gentlemen here to-day which would be greatly improved by drainage of the surrounding swamps. In addition to this, the drainage of these places would be of great benefit to the comfort and health of the communities in which they are situated, for these swamps are the breeding places of hosts of mosquitoes, which are terrible pests, and which modern science has shown to be the vehicles of malaria and other diseases.

The Chairman. I will call upon Mr. Richards; I think he has had some experience in this matter.

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* Biologist, Metropolitan Water Works.

† Journal of the American Microscopical Society, 1901.

FIG. 1. — BEFORE DRAINAGE.

FIG. 2. — AFTER DRAINAGE.

Mr. Walter H. Richards.* Mr. President and gentlemen, I happen to have had only one experience of this kind, and that was about ten years ago, when we drained a swamp of perhaps one hundred acres, by a method very similar to that the gentleman has described, except that we constructed our ditches on either side of the swamp and carried the upland water into our reservoir. The swamp happened to be so situated that we could take the water from the swamp and discharge that into another watershed outside of the watershed of our reservoir. By this means we took the water from the hillsides and carried it into our reservoir, and took the water from the swamp and carried it away from the reservoir. We were very successful in reducing the color. We did not make any exact determinations of the color, but the improvement was very apparent to the naked eye, from an extremely highly colored water to a water which was nearly white.

The Chairman. I will now call upon Mr. Sherman.

Mr. Charles W. Sherman.† Mr. President, I do not know that I can add anything to this discussion except a few words in regard to the figures upon which Mr. Larned has based the statements of the percentage of reduction of color. It fell to my lot to do most of the actual computing of those figures, and it is only fair to say that the reduction in color shown in many cases is the reduction in the color of the brook water near the point at which it is discharged into the reservoir, rather than near the outlet of the swamp. In the cases of the swamps which showed the largest percentage of reduction of color, which were forty and forty-eight, the observations, both before and after the improvement, were made at the outlet of the swamp, which was the same point as the point of discharge into the reservoir; that is, the swamp covered the whole area down to the reservoir, or to the main channel leading to it. In the other cases the swamps which were improved by ditching are situated rather near the limit of the watershed, and at a considerable distance from the reservoir proper, while the color observations were made at points near the reservoir; consequently the color before the improvement was made indicated the combined color of the water from the swamps and of a considerable quantity of upland water contributed to the brook below the swamp, that color, of course, being much less than the color of the water at the outlet of the swamp.

* Superintendent of Water Works, New London, Conn.
† Assistant Engineer, Metropolitan Water Works.

In the same way the color since the improvement was made, being at the same point, represents the color of a mixture of this same upland water and the water from the swamp which has been improved in color, an amount which, owing to lack of observation, is not directly determined. Consequently, where an improvement of perhaps fourteen or seventeen per cent. in color is shown, in all probability it means an actual improvement of from twenty-five to thirty-five per cent. in the color of the water discharged from the swamp in which the ditches were constructed. That point should be borne in mind in considering the apparently small percentage of reduction in color shown in some of the cases.

This condition is well shown in Fig. 2, which shows that part of the Sudbury watershed tributary to the open channel of the Wachusett Aqueduct, Sudbury Reservoir (formerly called No. 5), and Framingham Reservoir No. 3. The location of the ditches built is indicated by the heavy lines in or surrounding the swamps. The numbered points show *all* the points where observations of the color of the brook waters have been made at any time. The normal colors quoted by Mr. Larned were for the following points: —

Brooks tributary to Framingham Reservoir No. 3.

Brewer Brook, point (3).
Angelico Brook, point (5).

Brooks tributary to Sudbury Reservoir.

Deerfoot Brook, point (4).
Mowry Brook, point (15).
Broad Meadow Brook, point (20).

Brooks tributary to open channel of Wachusett Aqueduct.

Brigham's Pond Brook, point (4).
Crane Swamp, point (17).
Choate Brook, point (8).

Observations at other points were too few to warrant the computation of normal colors.

The Chairman. Mr. Brooks, I think, has had quite an experience with drainage on the Cambridge works.

Mr. Edwin C. Brooks.* I will say that although we have quite a large amount of swamp land tributary to our supply in Cambridge, very little has been done so far in the way of drainage. Our large

* Superintendent, Cambridge Water Works.

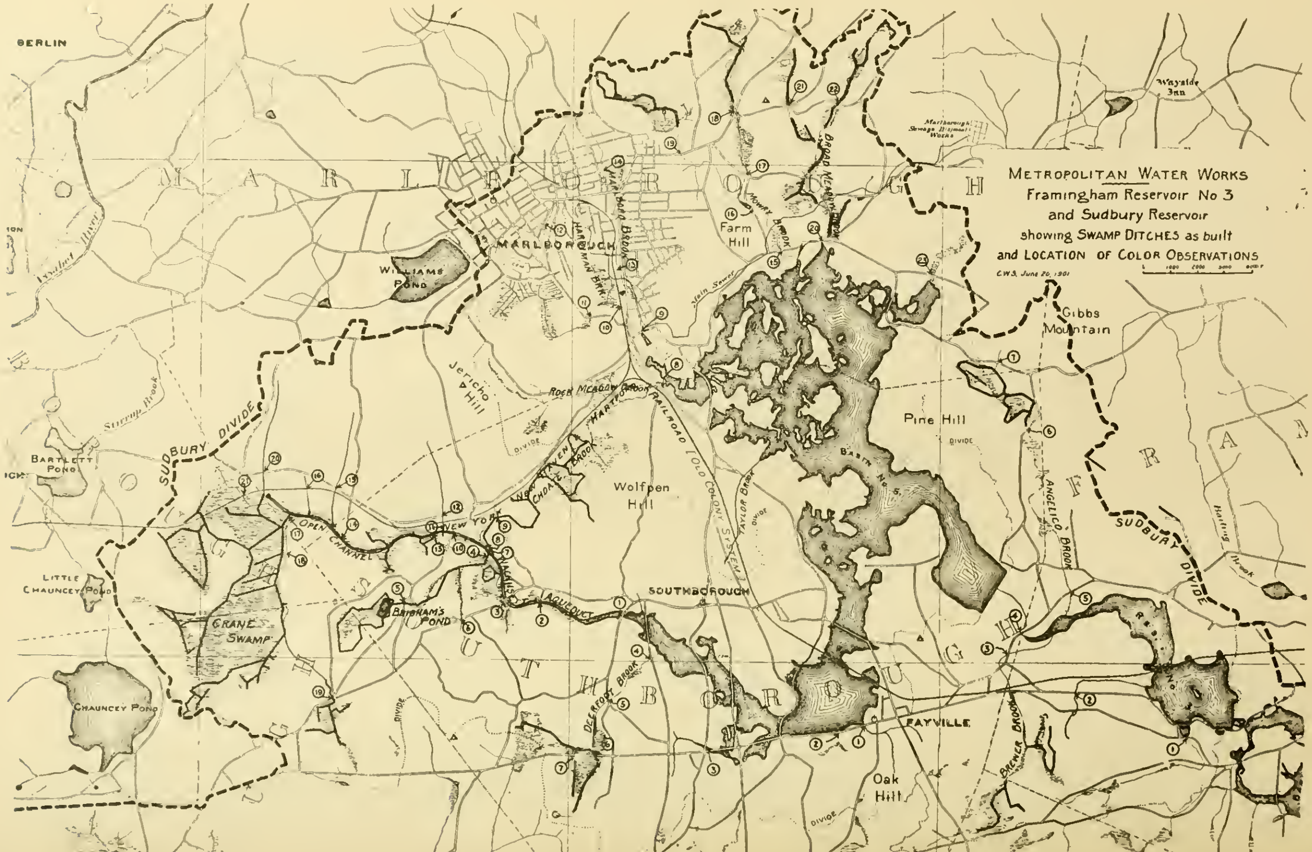
METROPOLITAN WATER WORKS
Framingham Reservoir No 3
and Sudbury Reservoir
showing SWAMP DITCHES as built
and LOCATION OF COLOR OBSERVATIONS
C.W.S. June 20, 1901
BERLIN
MARLBOROUGH
WILLIAMS POND
Farm Hill
Gibbs Mountain
Jericho Hill
Pine Hill
Wolfpen Hill
SOUTHBOROUGH
FAYVILLE
Oak Hill
BARTLETT POND
LITTLE CHAUNCEY POND
CHAUNCEY POND
CRANE SWAMP
BRIGHAM'S POND
SUDBURY DIVIDE
OPEN CHANNEL
AQUEDUCT
NEW YORK
HARTFORD
RAILROAD (OLD COLONY SYSTEM)
TAYLOR BROOK
ANGELICO BROOK
BREWER BROOK
DEERFOOT BROOK
MOWRY BROOK
BROAD MEADOW BROOK
HARMAN BRK.
Main Sewer
Stirrup Brook
Wayside Inn
Marlborough Sewage Disposal Works
DIVIDE

FIG. 2.

storage reservoir has operated very well to bleach out the water which comes from the Hobbs Brook section, and so the color has been kept down in that branch of the works. We expect, however, to go on with quite a system of ditching, which we think will improve matters very materially.

THE CHAIRMAN. At the time of our meeting in New Bedford, some twelve or fifteen years ago, we noticed that the water there was so highly discolored that it was almost impossible to tell it from other liquids which New Bedford is noted for. Perhaps Mr. Coggeshall can give us some information.

MR. R. C. P. COGGESHALL.* That water came from the old Acushnet Reservoir, which was the original supply and which is not now in use. This basin is surrounded by numerous swamps, which is the reason of this discoloration. Since the introduction of the new supply, in 1899, all our water is taken directly from Little Quittacas Pond.

MR. LARNED. An instance of organic contamination which may be of some interest, and perhaps is known to some of the gentlemen present, I had occasion to look into in connection with the water supply of Butte, Mont., a few years ago. They were constructing a new reservoir there, and, although it was unfinished, the reservoir had been allowed to partially fill, and they were using the water from it. At the head waters of the reservoir was a large swamp. At one season of the year, I think it was in June or July, the water became so foul that it was unsuited to almost all domestic uses. The color was a very dark chocolate. You could not destroy the odor by boiling; it tainted potatoes; it could not be used in making coffee; it was absolutely unfit to bathe in; and it was so noxious to smell that the City Fathers contemplated passing an ordinance forbidding its use for sprinkling the streets.

I have n't heard what was finally done. I believe one of the superintendents of the company was sent East to advise with experts in the matter, and swamp drainage was advised; and, as a preliminary betterment, they advised the construction of a flume leading from the head waters of the swamp around the swamp, which I believe was done. But it took a long time for the water to improve in the reservoir, and the community suffered meanwhile. It was harvest time for the owners of many little springs which are located in the valleys about there, the water being

* Superintendent, New Bedford Water Works.

peddled out, at the rate of from ten to fifteen cents a pail, through the town.

The Chairman. We should be glad to hear from any one else who has had any experience in this matter.

Mr. Leonard Metcalf.* There are one or two questions I should like to ask Mr. Larned. One is in regard to the grades at which some of these ditches have been laid, how flat the grades are; and the other is in regard to maintenance, whether it is found necessary once or twice a year to go over the ditches with a squilgee, or something of that sort, to clean them out, and how much material is washed in.

Mr. Larned. I stated, I believe, in the text of the paper, that the velocity was kept down to something under two feet per second. The grade which was followed to attain that velocity was generally about one foot in one thousand feet; and in many cases, where we did n't have a fall through the swamp and were required to secure this velocity in the water surface itself, we built deeper ditches, sometimes almost level.

In connection with the maintenance of the ditch, and perhaps the life of the ditch, it may be of interest to state that that will depend somewhat upon the board bottom being kept covered with water. Some of these ditches have been in existence now for about three years, and I believe they are in a fair state of preservation to-day. But it is conceivable with following periods of wet and dry the boards might rot rather rapidly.

The maintenance of the work requires one or two men to go over the ditches perhaps twice a year. In the spring of the year there may be a small amount of débris that has blown in or collected in the ditch, and that is very readily removed by a man taking a square-pointed shovel, — the width of the ditch is about eleven inches and a quarter, just a trifle more than the width of the shovel, — and he simply walks along the smooth bottom, pushing the shovel before him until he collects a shovelful of material, which he throws on the side of the ditch. There were about twenty-three thousand feet of ditches constructed the first season, and the total cost of cleaning them out, making needed repairs to the side slopes and paving due to frost upheaval, etc., amounted to about twenty-five dollars the first season, or about one dollar per one thousand feet.

Mr. Coggeshall. Previous to 1886 the only supply of the city

*Civil Engineer, Boston, Mass.

of New Bedford was from the Acushnet Reservoir. That supply became scant at times, and a drought in the latter part of 1886 necessitated prompt action in procuring an additional supply. Less than two miles north of the head waters of the Acushnet Reservoir is Quittacas Pond, which is now our source of supply. We put men at work and dug a ditch something less than a mile and a half long, and for over a mile the sides are laid with plank and braced. The grade of the bottom of the ditch is not over a foot in its whole length. That served the purpose for which it was intended up to the time the new supply was introduced in 1899, and it is in good condition to-day, so that it would be easy to get from three to four million gallons a day from Little Quittacas Pond into the Acushnet Reservoir through that ditch.

REPORT OF COMMITTEE ON UNIFORM STATISTICS.

JOSEPH E. BEALS, GEORGE F. CHACE, JOHN C. WHITNEY, *Committee.*

[*Presented January 8, 1902.*]

Mr. Joseph E. Beals, chairman of the Committee on Uniform Statistics, presented the following report : —

The Committee on Uniform Statistics, after spending considerable time upon the subject, although there were but two or three conferences of the whole committee, would recommend for adoption by the Association the form which has been in use for the last fifteen years, with a few alterations. The report, which we herewith submit, is practically the embodiment of the memoranda presented by the Editor of the JOURNAL at one of our conferences. Our report was written last September, but it failed to reach the Portland Convention. The writing of it was left to me, and, after I had prepared it, I sent it to the second member of the committee, Mr. Chace; and he sent it to the third member, Mr. Whitney; and Mr. Whitney says he sent it then to the Secretary of the Association, but it has disappeared from sight somewhere. The best I can do, therefore, in the way of a report now is to present to you the form which our Editor has had printed, and which embodies the ideas that were suggested when he was present at one of the meetings of the committee.*

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* Since the January meeting, the original report of the Committee has been found. It is as follows : —

SEPTEMBER 16, 1901.

To the Officers and Members of the New England Water Works Association :

GENTLEMEN, — The Committee appointed by you to consider the question of the preparation of statistics respectfully report that they have given the subject somewhat careful consideration, and would recommend that the old form which has been in use since the formation of the Association be, in the main, continued, with such few alterations as new and changed conditions seem to make advisable. For this purpose we have taken the blank schedule sent out by Mr. Sherman, our Editor, and noted such alterations as we deem advisable.

We would also advise that another section be added, covering information from plants which are making chemical and bacteriological examinations of water.

Respectfully submitted,

JOSEPH E. BEALS,
GEO. F. CHACE, } *Committee.*
J. C. WHITNEY,

I may say that we have received communications from eight or ten water organizations and statistical organizations asking for information, and in reply have sent to most of them the printed form that we have heretofore used. In very few cases have we received any suggestions from these other organizations, but in almost every instance the request has been made by them for us to furnish suggestions if we had any to make. We, therefore, present our own form, which we have used in the past, as the form which we recommend for us in the future, with a few changes, to some of which I will briefly call attention.

Under the head of "Pumping" there have been some changes in phraseology. For instance, "Description of Fuel Used" specifies "*a*. Kind," "*b*. If coal, what brand?" — the old headings were "*a*. Anthracite" and "*b*. Bituminous" — "*c*. Average price of coal per gross ton, delivered." We put it gross ton, as it stood in the former recommendation, but if I were going to alter that I should say, "per net ton," as I think 2 000 pounds is easier reckoning than 2 240. Then we insert 4*a*, "Amount of other fuel used," for we find that in some water works they use other fuels. Gasolene is being used quite largely, and naphtha, and in one or two places sawdust is used as fuel. I cannot from recollection specify all the alterations we have made under the head of "Pumping," but there are a few others.

Under the head of "Financial," we have modified the Maintenance table so as not to call for reports giving statistics for receipts for water for manufacturing purposes. We found when we came to tabulate the figures of receipts for manufacturing purposes that there was so much difference in the practice, that it was perhaps better to leave the word "manufacturing" out and simplify the rate; and we have therefore called for water rates by fixture, water rates by meter, and net receipts for water; and then for miscellaneous receipts for rent, repairs, sales, etc., and then for the total from consumers. Then come the receipts from public funds, F, G, H, I, and J, — hydrants, fountains, street watering, public buildings, and general appropriations. Probably in a good many cases the first four would be put under the head of "General Appropriations." I know that in the works that I represent we make a lump sum of those as a total from public funds. We found in tabulating that some of the works make a practice of carrying a balance forward, while others cover their balances into the town or city or district treasuries; but,

inasmuch as some of them bring forward a balance from year to year, we have provided a place for that in the table.

We have made very few changes under the head of "Financial — Construction." Instead of special rates of interest, we provide for the average rate of interest, and under "Expenditures" we have put in "Extension of meters." Under "Consumption" I think we suggest no change. Under the head of "Distribution," in the old form item No. 7 called for the number of leaks, and some cities returned the number per mile, and some the total number of leaks they actually had, so that in making up the statistics the Editor found it was sometimes quite difficult to tell which was meant. For instance, if a works reported, as some did, only one leak, it was difficult to tell whether it was one leak per mile or one leak in the whole system. I recollect that in the operation of my works during one year I not only did n't have one leak per mile, but not one leak in the whole system even. Then under "Services" we have had added one or two things, for example, No. 27, "Percentage of services metered," and No. 28, "Percentage of receipts from metered water." No. 23, "Average length of service," would be the total length of services divided by the number of services.

BLANK FORM FOR

SUMMARY OF STATISTICS.

Draw a line through items not applicable to the works under consideration, leaving the number on the items used *unchanged*.

Pumping. — (6.) Cross out "with" or "without," to indicate whether slip has been taken into consideration.

(8.) The dynamic head is indicated by pressure gage at pumping engine.

(10.) Only one formula for duty is here presented. It is hoped that for the sake of uniformity this formula will be strictly followed in this summary. Other methods may, if desired, be used in the body of the report.

(11, 12.) The pumping station expenses for this statement are to include only *Cost of Fuel*, *Salaries*, *Oil*, *Waste*, *and other supplies*, and *Repairs on Machinery and Boilers*.

(13, 14.) Item CC under *Financial* is the amount to be used in obtaining these figures.

Special Notice. — Please send a copy of each report in which a summary of statistics appears to the New England Water Works Association, 715 Tremont Temple, Boston.

SUMMARY OF STATISTICS

For the year ending ....

In form recommended by the New England Water Works Association.

...................................WATER WORKS.

....
(City or Town.) (County.) (State.)

Population by Census of 19 ....

Date of Construction, ...

By whom owned, ...

Source of supply, ...

Mode of supply, ...
(Whether gravity or pumping.)

PUMPING.

1. Builders of Pumping Machinery, ...

2. Description of Fuel used,
   - *a.* Kind, ...
   - *b.* If coal, what brand? ....
   - *c.* Average price of coal per gross ton, delivered, $ ....
   - *d.* Percentage of ash, ...
   - *e.* Wood, price per cord, $ ....
   - *f.* Other fuel, price, $ ....

3. Coal consumed for the year, ...lbs.

4. [Pounds of wood consumed] ÷ 3 = equivalent amount of coal, ...lbs.

4*a*. Amount of other fuel used, ...

5. Total equivalent coal consumed for the year = (3) + (4), ...lbs.

6. Total pumpage for the year, ... gallons, $\left\{\begin{matrix}\text{with}\\ \text{without}\end{matrix}\right\}$ allowance for slip.

7. Average static head against which pumps work, ...feet.

8. Average dynamic head against which pumps work, ... feet.

9. Number of gallons pumped per pound of equivalent coal (5), ...

10. $$\text{Duty} = \frac{\text{gallons pumped (6)} \times 8.34 \text{ (lbs.)} \times 100 \times \text{dynamic head (8)}}{\text{Total fuel consumed (5)}} = \ldots\ldots\ldots$$

Cost of pumping, figured on pumping station expenses, viz., $ ....

11. Per million gallons pumped, $ ....

12. Per million gallons raised one foot (dynamic), $ ....

Cost of pumping, figured on total maintenance, viz., $ ....

13. Per million gallons pumped, $ ....

14. Per million gallons raised one foot (dynamic), $ ....

FINANCIAL.

MAINTENANCE.

Receipts.			Expenditures.		
Balance brought forward		$	AA. Management and repairs		$
From Consumers:			BB. Interest on bonds		
A. Water rates, fixture, $			CC. Total maintenance for year		$
B. Water rates, meter,			DD. Balance		
C. Net receipts for water, (A) + (B), $					
D. Miscellaneous (rent, repairs, sales, etc.)					
E. Total from consumers		$			
From Public Funds:					
F. Hydrants	$				
G. Fountains					
H. Street watering					
I. Public buildings					
J. Gen'l appropriations					
Total from public funds					
K. Gross receipts from all sources		$	K. Total		$

FINANCIAL.

CONSTRUCTION.

Receipts.			Expenditures.		
Q.	From balance of previous year	$	FF.	Extension of mains	$
R.	,, Bonds issued		GG.	Extension of services	
S.	,, Appropriations from tax levy		HH.	Extension of meters	
T.	Transferred from maintenance account		II.	Special (reservoirs, pumps, etc.)	
U.	From other sources		JJ.	Total construction for year	$
			KK.	Balance	
V.	Total	$	V.	Total	$

W. Net cost of works to date . . . . . $

X. Bonded debt at date . . . . . . $

Y. Value of sinking fund at date . . . . $

Z. Average rate of interest, ... per cent.

CONSUMPTION.

1. Estimated total population at date,....................
2. Estimated population on lines of pipe,....................
3. Estimated population supplied,....................
4. Total consumption for the year,.................... gallons.
5. Passed through meters.................... gallons.
6. Percentage of consumption metered,....................
7. Average daily consumption,.................... gallons.
8. Gallons per day to each inhabitant (1),....................
9. Gallons per day to each consumer (3),....................
10. Gallons per day to each tap (taps in use),....................

DISTRIBUTION.

Mains.

1. Kind of pipe,....................
2. Sizes, from.......... inch to .... inch.
3. Extended .... feet during year.
4. Discontinued .... feet during year.
5. Total now in use,.......... miles.
6. Cost of repairs per mile, $..........
7. Number of leaks per mile,..........
8. Length of pipes less than 4 inches diam.,.......... miles.
9. Number of hydrants added during year (public and private),..........
10. Number of hydrants (public and private) now in use,..........
11. Number of stop gates added during year,..........
12. Number of stop gates now in use, ...
13. Number of stop gates smaller than 4-inch,..........
14. Number of blow-off gates,..........
15. Range of pressure on mains at center of town,.......... lbs. to .... lbs.

Services.

16. Kind of pipe,..........
17. Sizes,..........
18. Extended,.......... feet.
19. Discontinued,.......... feet.
20. Total now in use,.......... miles.
21. Number of service taps added during year,..........
22. Number now in use,..........
23. Average length of service,.......... feet.
24. Average cost of service for the year, $ ....
25. Number of meters added,..........
26. Number now in use,..........
27. Percentage of services metered,..........
28. Percentage of receipts from metered water (B ÷ C),..........
29. Number of motors and elevators added,..........
30. Number now in use,..........
31. Number of standpipes for street watering,..........

DISCUSSION.

Mr. R. C. P. Coggeshall.* I suppose the number of leaks per mile you would have to express in decimal. That is, if there were one hundred miles of mains in a system and there were twenty-five leaks, it would be twenty-five hundredths of a leak for each mile.

Mr. Beals. That is what it would be, twenty-five hundredths of a leak per mile.

Mr. Coggeshall. I don't see any other way to express it.

Mr. Beals. We changed that because some report the number of leaks during the year and some report the number of leaks per mile. Of course, twenty-five hundredths of a leak would be a small figure, but it would make the amount of leakage clearer than if there were stated to be twenty-five leaks and you did n't look to see that there were one hundred miles of pipe.

Mr. M. N. Baker† (*by letter*). A committee of the Central States Water Works Association has recommended the use of the present New England schedule, pending further developments. The American Water Works Association, at its last meeting, appointed a committee to coöperate with others in this matter. A committee of the American Society of Municipal Improvements several years ago submitted a schedule for water-works statistics.

It is now hoped that by next spring the various committees named above, together with committees from the National Municipal League and the American Economic Association, may agree upon a common schedule. The chief difficulty is to devise a summary of statistics brief and simple enough for general adoption, yet sufficiently comprehensive to include many of the details of water-works practice eagerly sought by the water-works officials of the present day.

It has been suggested that two schedules be provided — a sort of longer and shorter catechism. Why could not the original New England schedule serve as the shorter, and that of the American Society of Municipal Improvements be adopted as the longer summary? It has been urged that the Municipal Improvement schedule contains everything that is in the New England, and much besides. I have compared the two with some care and find that this is not far from the truth. Certainly it would be an easy matter to insure exact correspondence, except in the matter of length.

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* Superintendent of Water Works, New Bedford, Mass.
† Associate Editor, *Engineering News*.

I hope it may prove possible for the New England Water Works Association to preserve its old schedule practically unchanged for some months longer, until there has been one more attempt to bring the various societies together. If that attempt does not succeed I shall then recommend the several committees of which I am a member to adopt the then existing schedule of the New England Water Works Association. Of course there can be no harm in making a few minor changes in the schedule meanwhile, so long as they leave the general plan and scope of the New England schedule open, and do not commit it to seeming independence of action.

If it seems wise to the other members of the Association, I suggest: That the present committee be continued, with power to coöperate with committees of other societies in an effort to secure the adoption of a uniform summary of water-works statistics suitable for annual reports, and ultimately at least a nearer approach to uniformity in water-works accounting.

Mr. Beals. The committee recognized that possibly the Association might desire to add one or two items regarding purification and filtration of waters, and the chemical and perhaps biological examinations. As I remember it now, that was recommended in the report which was prepared. I want to say further that our efforts have been to simplify these statistics rather than to add complications. Many of our members make up their reports at about this time of the year, which is a very busy season with them, and it sometimes would require more labor than we feel we have time to put into it, especially if we should add everything that some people, whom I may call cranks on the subject of statistics, want to have added to the statistics. We could very easily double the length of these tables by adding everything we could think of to ask for in the way of statistics, but I fear the result would be that we would find we would n't get anything answered. The fact now is that, up to the beginning of 1900, we were only able to get twenty-eight reports, and those were not all from our own members, either; but they were all we could get from reported statistics in the annual reports. Since then our Editor, by personal correspondence and sending out blanks similar to this, has succeeded in getting sixty reports. But the fact that he could only get sixty shows either that there is a desire not to make such reports, or else that our members have n't time to fill in the information. We hope that by making the thing very simple we may be able to get from the busy members better returns

than we would if we made the blank so extended and so elaborate that gentlemen would merely look at it and throw it one side.

Mr. C. W. Sherman.* So many members had gone out near the close of our last meeting, that it may be well for me now to call attention to the fact that at my request, as I wanted to send the blanks out so that the superintendents could use them in making up their returns for the past year, the meeting then endorsed the use of this printed form for summarizing the reports for 1901. Of course we did not accept it beyond that.

Mr. Coggeshall. I should like to ask Mr. Beals, the chairman of the committee, if he does not think it would be a good idea to add Mr. Baker to the committee, as he seems to have made a special study of this subject, and then continue the committee for a while longer.

Mr. Beals. As Mr. Baker is a member of this organization, as well as of several others of a kindred nature, I think it might aid in bringing about a unity of sentiment if he were either added to the committee or substituted for some one of the members. I should be perfectly willing that the committee be discharged and a new one be appointed with Mr. Baker at the head of it.

Mr. Dexter Brackett. To put this in some concrete form, I will move, as I believe that the subject is one of importance, and in view of the fact that it may be wise to include some other statistics, that the committee be continued, with the addition of Mr. M. N. Baker and of our Editor, Mr. C. W. Sherman, as members, to make such further investigation as they may deem expedient.

Adopted.

* Editor, Journal of the N. E. W. W. Association.

PROCEEDINGS.

December Meeting.

Young's Hotel, Boston, Mass.,
December 11, 1901.

Past President Horace G. Holden in the chair.

The attendance was as follows: —

Members.

Charles H. Baldwin, Lewis M. Bancroft, George W. Batchelder, Joseph E. Beals, James W. Blackmer, George Bowers, Dexter Brackett, Fred Brooks, George F. Chace, John C. Chase, Freeman C. Coffin, R. C. P. Coggeshall, J. W. Crawford, F. F. Forbes, W. E. Foss, F. B. French, F. L. Fuller, J. F. Gleason, Albert S. Glover, Amos A. Gould, J. A. Gould, Frank E. Hall, John O. Hall, L. M. Hastings, Horace G. Holden, J. L. Howard, E. W. Kent, Willard Kent, C. F. Knowlton. Edward S. Larned, Charles S. Lord, A. E. Martin, William E. Maybury, Leonard Metcalf, H. N. Parker, J. H. Perkins, Macy S. Pope, J. B. Putnam, W. H. Richards, W. W. Robertson, Harley E. Royce, Caleb M. Saville, Walter H. Sears, P. P. Sharples, Charles W. Sherman, H. O. Smith, Frederic P. Stearns, J. J. Sullivan, William F. Sullivan, Charles N. Taylor, Lucian A. Taylor, H. L. Thomas, R. J. Thomas, William H. Thomas, D. N. Tower, W. H. Vaughn, W. W. Wade, William Wheeler, John C. Whitney, G. E. Wilde.

Associates.

The George F. Blake Mfg. Co., by A. F. Hall; Harold L. Bond & Co., by Harold L. Bond; Builders Iron Foundry, by F. N. Connet; Chadwick-Boston Lead Co., by A. H. Brodrick; Chapman Valve Co., by Edward F. Hughes; Charles A. Claflin; Coffin Valve Co., by H. L. Weston; M. J. Drummond, by Walter E. Drummond; Garlock Packing Co., by Horace A. Hart; Hersey Mfg. Co., by Albert S. Glover; Henry F. Jenks; Lead-Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; A. P. Smith Mfg. Co., by W. H. Van Winkle; Sumner & Goodwin Co., by F. D. Sumner; United States Cast Iron Pipe and Foundry Co., by L. R. Lemoine; Walworth Mfg. Co., by R. S. Mitchell; R. D. Wood & Co., by E. F. Krewson.

Guests.

H. V. Macksey, Boston Water Works, Boston, Mass.; L. S. Doten, C. E., Boston, Mass.; Samuel C. Hunt, Member Water Board, New Bedford, Mass.; W. C. Livermore, Holyoke, Mass.; M. J. Dowd and H. C. Taft, Water Commissioners, Lowell, Mass.; James T. Stevens, Water Commissioner, Braintree, Mass.; C. A. Donovan, Member Water Board, Lawrence, Mass.; H. C. Stillwell, Marion, Ohio; E. J. Sanburg, Quincy, Mass.; E. P. Walters, A. F. Bridgman, Metropolitan Water Works, Boston, Mass.; F. A. Morrison, W. H. Greenwood, F. W. Blanchard, Boston, Mass.; L. P. Woods, Boston, Mass.; W. I. Edwards, Londonderry, N. S.

Edward S. Larned, C. E., Metropolitan Water Works, South Framingham, Mass., read a paper entitled "Swamp Drainage for Watershed Improvement." The paper was discussed by Horatio N. Parker, Biologist, Metropolitan Water Works; Walter H. Richards, Superintendent, New London; Charles W. Sherman, Assistant Engineer, Metropolitan Water Works; Edwin C. Brooks, Superintendent, Cambridge; R. C. P. Coggeshall, Superintendent, New Bedford, and Leonard Metcalf, Civil Engineer, Boston.

The report of the Committee on "Standard Specifications for Cast-iron Pipe" was presented by Mr. Freeman C. Coffin, chairman of the committee. Written communications discussing the report were received from Emil L. Nuebling, Engineer and Superintendent of the Water Department, Reading, Pa.; Frank A. McInnes, Assistant Engineer, Engineering Department, Boston, and Louis H. Knapp, Engineer, Buffalo Water Works.

There was also oral discussion by L. R. Lemoine, representing the United States Cast Iron Pipe and Foundry Co.; Edmund F. Krewson, representing R. D. Wood & Co.; W. I. Edwards, representing the Montreal Pipe and Foundry Co.; Dexter Brackett, Engineer Distribution Department, Metropolitan Water Works, and also a member of the committee; Walter H. Richards, Superintendent, New London; H. V. Macksey, of the Boston Water Works; J. A. Gould, Chief Engineer of the Brookline & Dorchester Gas Light Companies, and Frank L. Fuller and E. H. Gowing, Civil Engineers.

On motion of Mr. Robert J. Thomas it was voted to continue the discussion of the report at the January meeting.

Summary of Statistics.

Mr. Charles W. Sherman. Before the meeting adjourns, as it is evidently too late to receive the report of the Committee on Uni-

form Statistics this afternoon, I should like to call attention to one matter, which will take but a moment of your time, in that connection. I have anticipated the acceptance of what, perhaps, I might call the preliminary report of the committee, to the extent of having blank forms printed for use in preparing the annual reports for 1901. If we wait until another meeting to endorse the use of these, it will be too late for many of the members. I might say, as many of you know, that I was in consultation with the committee at its meeting before the Portland Convention, and at that time they decided to recommend certain slight changes in the form now in use, and these blanks which I have had printed embody those recommendations. I do not wish to have you adopt the form offhand in this way for indefinite future use; but I do wish that this meeting would pass a vote authorizing its use for the current year, as it is but a slight modification of the form previously used. I will make that as a motion, that the Association endorse the use of the form now printed, including the recommendations of the committee, for the reports of 1901.

Adopted.

Mr. R. J. Thomas. I wish to state for the information of the members who may wish to buy pipe before the specifications are settled upon, that if they will consult the pages of the Journal they will find the advertisements there of foundrymen who are willing to do work as required by these specifications which have been submitted.

Adjourned.

PROCEEDINGS.

Annual Meeting.

Young's Hotel,
Boston, January 8, 1902.

President Crandall in the chair.

The following members and guests were present: —

Members.

Lewis M. Bancroft, Roland D. Barnes, Joseph E. Beals, James F. Bigelow, George Bowers, Dexter Brackett, Fred. Brooks, L. Z. Carpenter. George Cassell, George F. Chace, G. L. Chapin, John C. Chase, Freeman C. Coffin, R. C. P. Coggeshall, F. H. Crandall, J. W. Crawford, M. F. Collins, L. E. Daboll, A. O. Doane, H. A. Fiske, F. F. Forbes, J. F. Gleason, Albert S. Glover, J. A. Gould, E. H. Gowing, J. O. Hall, J. C. Hammond, Jr., D. A. Harris, H. G. Holden, E. W. Kent, Willard Kent, George A. Kimball, James W. Locke, Frank E. Merrill, Leonard Metcalf, Macy S. Pope, C. E. Riley, H. E. Royce. W. H. Sears, E. M. Shedd, Charles W. Sherman, J. Waldo Smith, George H. Snell, George A. Stacy, F. P. Stearns, William F. Sullivan, C. N. Taylor, L. A. Taylor, D. N. Tower, George W. Travis, W. H. Vaughn, William W. Wade, William Wheeler, George E. Wilde, F. B. Wilkins.

Associates.

Harold L. Bond & Co., by Harold L. Bond; Builders Iron Foundry, by F. N. Connet and H. J. Burroughs; Chapman Valve Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; Hersey Mfg. Co., by Albert S. Glover; Lead-Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; Union Water Meter Co., by J. P. K. Otis.

Guests.

H. V. Macksey, Boston Water Works, Boston, Mass.; T. J. Burke, Water Commissioner, Brookline, Mass.; G. S. Hedge, Boston, Mass.; Charles Donovan and A. H. Robinson, Water Commissioners, Lawrence, Mass.

The following applicants were elected to membership, having been recommended by the Executive Committee: —

Resident Members.

Leonard S. Doten, Boston; James F. Stevens, Brockton, Chairman Brockton Water Board.

Non-Resident Members.

Thomas Archibald MacLean, Charlottetown, P. E. I.; James M. Betton, New York.

Associate.

Montreal Pipe Foundry Co., Ltd., Manufacturers of Cast-Iron Water Pipes and Special Castings, Londonderry, N. S.

The President appointed Messrs. D. N. Tower and C. N. Taylor as tellers to count the ballots for officers for the year 1902.

PRESIDENT'S ADDRESS.

President F. H. Crandall, of Burlington, Vt., then delivered the following address: —

With matters of considerable interest and importance pressing for attention, I will take no more of your time than necessary to briefly touch upon the subjects upon which it has become customary to expect a word from a retiring president.

Before taking up the perfunctory part of the program, I wish to thank you for the honor conferred upon me a year ago, as well as for your forbearance and assistance since.

The hope expressed by our President at the Burlington Convention, in 1895, that each of his successors might, in turn, enjoy the pleasure then accorded him, of reporting the Association larger, stronger, and more powerful for good than ever before, has been amply gratified. We can again congratulate ourselves on the completion of a year of wonted growth and activity.

The results of the provision, made at the Rutland Convention, for the improvement of the JOURNAL, we have all had an opportunity to see in the JOURNAL itself, though I doubt if any of us half appreciate the untiring diligence of our able Editor. The index which Mr. Sherman has under way, when put up in card form, and kept at headquarters, up to date, will materially add to the value of

headquarters. I had hoped to approve a bill for this card index, but I understand that though, like most good things, slow in coming, it is on the way.

The work of the past season I will not attempt to review. Matters of interest and importance have occupied our attention at each meeting, and the indefatigable efforts of our genial Secretary have resulted in placing in his hands several more interesting and instructive papers than there has thus far been opportunity to present at the meetings of the Association.

Our financial condition is, according to the Micawberian standard, one of perfect happiness. Our expenditures have been less than our receipts, and the balance, to-day reported by our Treasurer, is less than that of his last report only because we have paid several bills incurred during preceding years as well as all bills contracted during the year just past.

Death has, during the past year, claimed eight of our members: William H. Laing, Superintendent and Secretary, Racine Water Company, Racine, Wis.; Samuel G. Stoddard, Jr., Superintendent and Engineer, Bridgeport Hydraulic Company, Bridgeport, Conn.; Patrick F. Crilly, Superintendent, Woburn Water Works, Woburn, Mass.; Jo H. Linsley, Director Vermont State Laboratory, Burlington, Vt.; Henry W. Rogers, Haverhill, Mass.; John H. Decker, Brooklyn, N. Y.; James M. Battles, Superintendent, St. Mary's House for Sailors, East Boston, Mass.; Arnold H. Salisbury, Superintendent, Lawrence Water Works, Lawrence, Mass.

To the untiring energy and persistence of Dr. Jo H. Linsley is due the recent notable advancement in matters pertaining to the public health of Vermont.

Henry W. Rogers was a founder and past-president of the Association.

John H. Decker was a founder of the American Water Works Association.

The yeoman service rendered by James M. Battles, here at home, where charity and missionary work should begin, will long be remembered in this port.

A. H. Salisbury, owing to his general temperament and frequent attendance upon our meetings, was probably the most well-known among us of those who have been called to the other shore. As at this time we devote a brief space to those who, during the year past, have passed away, we may derive some comfort and encouragement

from the knowledge that "no life can be pure in its purpose and strong in its strife, and all life not be purer and stronger thereby."

The water supply engineer of to-day has a delicate and thankless task on his hands. The demand for the learned and intricate is not alone made upon the medical profession, though the case of the lady seeking to learn why some people are born blind is a most striking example of the prevalent demand. Many of you, no doubt, recollect the reply of the learned oculist. He said, "I suppose, madam, that the phenomenon of which you speak is the result of the parties in question having come into this world physically incapacitated to perceive the light," whereupon the good lady gave expression to her appreciation of a physical education, remarking that she had asked her husband the same question many times, and all that she could get out of him was, "Kase they is." It is up to the engineering profession to cause an engineering education to be equally appreciated.

If the supply be short because more water is wasted than can be used, public opinion requires that the remedy be sought in increased pumping facilities, or in elaborate plans for an increased supply, rather than in the conservation of the supply at hand.

When considering the huge discrepancy usually existing between the pumping record and the amount of water accounted for, public opinion requires that evaporation, the error of the meter, the aggregate of a vast number of small leaks, and, perhaps, in a general way, losses from other causes, be marshaled in explanation of what is, by popular fallacy, designated a strange and unaccountable condition.

Public opinion in these matters, striving for an intricate and learned explanation of a plain and simple proposition, stands in much the same position as did the Maine editor, who sought to explain, in a supernatural manner, the advent of his first-born. He said: —

"One night as old St. Peter slept,
He left the doors of heaven ajar,
When through a little angel crept,
And came down with a falling star.

"One summer, as the blessed beams
Approached, my blushing bride
Awakened from some pleasant dreams,
And found the little angel by her side.

"God grant but this, I ask no more,
That when he leaves this world of pain,
He'll wing his way to that bright shore,
And find the path to heaven again."

And yet no one has come forward to set public opinion right.

You, no doubt, remember that John G. Saxe, taking issue with the down-east editor, stated the plain, unvarnished facts in regard to that little every-day occurrence, in a manner so straightforward and convincing as to leave no room for argument. He said, speaking for St. Peter: —

"Full eighteen hundred years or more,
I 've kept my doors securely fast,
There has no little angel strayed
Or recreant through the portal passed.

"I have not slept, as you suppose,
Nor left the gates of heaven ajar,
Nor has a little angel strayed
Or gone down with a falling star.

"Go ask that blushing bride, and see
If she don't frankly own and say,
That when she found that angel babe,
She found it in the good old way.

"God grant but this, I ask no more,
That should your numbers still enlarge,
You 'll not do as you 've done before,
And lay it to old Peter's charge."

REPORT OF EXECUTIVE COMMITTEE.

President Crandall. I had not understood until this moment that I was expected to make a report for the Executive Committee, but inasmuch as I am now informed that I am, I will say that the affairs of the Association appear to the Executive Committee, so far as we have consulted with each other, to have been carried on during the past year in a satisfactory and businesslike manner. The only suggestions we have to make are that in the future the report of the officer who is in position to know in regard to the matter should include a statement of the liabilities and assets of the Association; and that the place for holding the annual convention should be fixed upon at as early a date as possible.

REPORT OF THE TREASURER AND FINANCE COMMITTEE.

Mr. Lewis M. Bancroft, Treasurer, then submitted his report. On motion of Mr. Coggeshall the reading of the details was dispensed with. The report is as follows: —

Lewis M. Bancroft, Treasurer, *in account with*

RECEIPTS.

1901.			
January 1.	Balance on hand		$2 108.24
16.	Received of Willard Kent, Secretary	$173.50	
February 9.	,, ,, ,, ,, ,,	301.62	
18.	,, ,, ,, ,, ,,	211.25	
March 5.	,, ,, ,, ,, ,,	216.00	
22.	,, ,, ,, ,, ,,	61.95	
April 4.	,, ,, ,, ,, ,,	125.23	
May 7.	,, ,, ,, ,, ,,	86.90	
13.	,, ,, ,, ,, ,,	172.80	
31.	,, ,, ,, ,, ,,	119.50	
June 15.	,, ,, ,, ,, ,,	172.95	
28.	,, ,, ,, ,, ,,	93.30	
July 10.	,, ,, ,, ,, ,,	379.50	
17.	,, ,, ,, ,, ,,	354.00	
August 16.	,, ,, ,, ,, ,,	359.00	
October 9.	,, ,, ,, ,, ,,	233.40	
November 13.	,, ,, ,, ,, ,,	153.78	
21.	,, ,, ,, ,, ,,	360.80	
December 2.	,, ,, ,, ,, ,,	193.95	
1902.			
January 8.	,, ,, ,, ,, ,,	424.45	4 193.88
1901.			
August 16.	Dividend, Peoples Savings Bank		43.72
October 9.	Interest on deposit, National Bank		.95
			$6 346.79

EXPENDITURES.

1901.		
January 4.	Bacon & Burpee, reporting Nov. and Dec., 1901, meetings	$27.50
	Samuel Usher, printing December, 1900, JOURNAL	406.20
12.	Willard Kent, salary and expenses to January 1, 1901	29.17
15.	D. Gillies' Sons, printing	18.55
	Association of Engineering Societies, cuts	2.75
	Charles W. Sherman, salary and expenses to January 1	30.57
16.	Francis L. Pratt, music at January meeting	20.00
22.	J. M. Ham, salary and expenses to January 15	26.76
	Thomas P. Taylor, stereopticon, January 9	10.00
February 15.	Hub Engraving Co., plates	42.60
	Hobbs & Warren Co., letter book and cards	1.95
	D. Gillies' Sons, stamped envelopes and printing	124.25
21.	Francis L. Pratt, music, February meeting	20.00
	J. M. Ham, salary and expenses to February 15	32.27
	Olmsted Bros., illustrations for paper at Rutland	20.00
27.	L. M. Bancroft, revenue stamps	2.00
March 6.	Boston Society of Civil Engineers, rent to February 28	100.00
	Hub Engraving Co., plates	8.52
13.	W. N. Hughes, printing membership list, etc.	89.53
	D. Gillies' Sons, printing	3.25
	Samuel Usher, printing	1.50
	Hobbs & Warren Co., cards	.40
19.	Francis L. Pratt, music, March meeting	20.00
21.	Samuel Usher, printing March JOURNAL	262.30
25.	J. M. Ham, salary and expenses to March 15	28.79
April 4.	Willard Kent, salary and expenses to April 1	101.25
	Charles W. Sherman, salary and expenses to April 1	84.75
29.	Bacon & Burpee, report of Jan., Feb., and March meetings . .	80.25
	Robert J. Thomas, advertising agent, to April 1	41.75
	D. Gillies' Sons, printing	5.02
May 16.	J. M. Ham, salary and expenses to April 15	26.75
	Hub Engraving Co., cuts	25.08
	Hobbs & Warren Co., book and cards	3.35
	Samuel Usher, printing	13.00
23.	J. C. Whitney, expenses, 1899	70.78
June 18.	W. N. Hughes, envelopes for JOURNALS	45.00
	D. Gillies' Sons, printing circulars	4.75
	Boston Society of Civil Engineers, rent to May 31	100.00
	J. M. Ham, salary and expenses to June 15	56.74
July 22.	Samuel Usher, printing June JOURNAL	267.05
	Charles W. Sherman, salary and expenses to July 1	82.85
	Willard Kent, salary to July 1	50.00
	J. M. Ham, salary and expenses to July 15	26.91
	Robert J. Thomas, advertising agent, to July 1	61.40
	Hobbs & Warren Co., cards	.46
August 27.	Hub Engraving Co., cuts	1.47
	D. Gillies' Sons, receipt book and envelopes	33.50
September 17.	Charles W. Sherman, salary and expenses to October 1	78.34
23.	J. M. Ham, salary and expenses to September 15	50.80
October 10.	J. M. Ham, salary and expenses to October 15	47.03
	D. Gillies' Sons, postal cards and printing	24.25
	Boston Society of Civil Engineers, rent to August 31	100.00
	Willard Kent, salary and expenses to October 1	73.27
19.	Robert J. Thomas, advertising agent, to October 1	70.25
November 14.	D. Gillies' Sons, printing	4.25
	W. N. Hughes, printing	5.25
	J. M. Ham, salary and expenses to November 15	27.01
	Samuel Usher, printing September JOURNAL	353.25
	Bacon & Burpee, report of Annual Convention	45.00
December 20.	Hobbs & Warren Co., stationery	2.25
	W. N. Hughes, binding and cards	15.00
	J. M. Ham, salary and expenses to January 1, 1902	44.34
	Boston Society of Civil Engineers, rent to November 30	100.00
	Hub Engraving Co., plates	25.81
	Francis L. Pratt, music, December meeting	20.00
	Willard Kent, salary and expenses to January 1, 1902	81.00
	Charles W. Sherman, salary and expenses to January 1, 1902 . .	80.00
	Thomas P. Taylor, stereopticon, December meeting	10.00
	Robert J. Thomas, advertising agent, to January 1, 1902	70.95
31.	D. Gillies' Sons, stamped envelopes and printing	88.10
	Bacon & Burpee, reporting November and December meetings .	25.75
	Samuel Usher, printing December JOURNAL	307.75
	W. N. Hughes, billheads	5.00
	Henry F. Jenks, expenses, Committee on Exhibits of Associates	17.60
		$4 283.22

BALANCE ON HAND.

Cash	$424.45	
Deposit, Peoples Savings Bank, Worcester	1 293.42	
Deposit, Mechanics Savings Bank, Reading	300.00	
Deposit, First National Bank, Reading	45.70	2 063.57
		$6 346.79

Mr. Coggeshall. How does the balance compare with the balance at the date of the last report?

Mr. Bancroft. It is $44.67 less than at the date of the last report. There have been paid during the year bills contracted during the years 1899 and 1900, amounting to $70.78 and $514.74, respectively. The receipts for the year 1901 were $4 238.55, and the bills paid for the year 1901 were $3 697.70, leaving a balance of receipts over expenditures for the year of $540.85. I know of no outstanding bills which we owe.

On motion of Mr. Brackett, it was voted to accept and print the report of the Treasurer.

Mr. J. W. Crawford, for the Finance Committee, stated that the report of the Treasurer had been examined and found to be correctly cast, with proper vouchers for all expenditures, and the balance correct as stated.

On motion of Mr. Brackett, the report of the Finance Committee was accepted.

REPORT OF THE SECRETARY.

The Secretary, Mr. Willard Kent, submitted the following: —

Mr. President and Gentlemen of the New England Water Works Association, — I have the honor to submit the following report as Secretary: —

Statistics Relating to Membership for Year Ending December 31, 1901.

January 1, 1901.	Total membership			606

ACTIVE MEMBERS.

January 1, 1901.	Total active membership		530
	Withdrawals:		
	Resignations	8	
	Dropped	61	
	Died	8	77
			453
	Initiations:		
	January	6	
	February	1	

	March	7		
	June	9		
	September	12		
	November	5		
	December	0	40	493

HONORARY MEMBERS.

January 1, 1901.	Honorary members	4	
January 1, 1902.	Honorary members		4

ASSOCIATES.

January 1, 1901.	Total associate membership		72	
	Withdrawals:			
	Resigned	9		
	Dropped	9	18	
			54	
	Initiations:			
	January	1		
	February	1		
	March	0		
	June	1		
	September	1		
	November	0		
	December	0	4	58
January 1, 1902.	Total membership			555

SUMMARY OF RECEIPTS OF THE NEW ENGLAND WATER WORKS ASSOCIATION FOR THE YEAR ENDING DECEMBER 31, 1901.

Dues	$1 759.00
Advertising	1 750.50
JOURNALS sold	315.68
Initiation	266.00
Sundry	75.95
Subscriptions	26.75
Total	$4 193.88

SUMMARY OF EXPENSES OF THE NEW ENGLAND WATER WORKS ASSOCIATION FOR YEAR ENDING DECEMBER 31, 1901.

JOURNAL	$1 366.55
Stationery and printing	414.78
Rent	400.00
Assistant Secretary	312.50

Editor	300.00
Expenses	259.30
Advertising Agent	244.35
Secretary	200.00
Stenographer	151.00
Music	80.00
Stereopticon	20.00
Slides	20.00
Total	$3 768.48

Amount of Receipts above Expenditures $425.40

At the present time there is due the Association $520.50 for annual dues, $408.75 for advertising, and $10.75 for sundry items, such as reprints, etc., making a total of $940. I know of no outstanding bills against the Association.

Respectfully submitted,

(Signed) WILLARD KENT,
Secretary.

On motion of Mr. Coggeshall, the report was accepted and ordered printed in the JOURNAL.

Mr. Charles W. Sherman, Editor, then read his report.

REPORT OF THE EDITOR OF THE JOURNAL.

BOSTON, January 1, 1902.

To the President and Members of the New England Water Works Association:

The following is a report for Volume XV of the JOURNAL, including the six issues from September, 1900, to December, 1901, and covering the nineteen months from June 1, 1900, to date.

Table No. 1 gives a detailed statement of the material in this volume of the JOURNAL; while Tables Nos. 2 and 3 show in detail the receipts and expenses, on account of the JOURNAL, for the nineteen months and for the year, respectively. The increase in the amount of advertising since the election of Mr. R. J. Thomas as Advertising Agent is worthy of note, as is also the fact that the net cost of the JOURNAL for the year 1901, as shown by Table No. 3, was nothing. It is to be noted that no part of the dues from members is included in the receipts.

TABLE No. 1. — STATEMENT OF MATERIAL IN VOLUME XV, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1900-01.

Number.	Date of Issue.	Number of Pages of: Papers.	Proceedings.	Volume Index, etc.	Total Text.	Advertisements.	Covers and Contents.	Inset Plates.	Membership List.	Total.	Cuts.
1	September, 1900..	93	3	...	96	20	5	4	...	125	3
2	December, 1900...	97	31	...	128	18	5	10	...	161	12
3	March, 1901........	63	11	...	74	22	5	11	48	160	9
4	June, 1901..........	61	7	...	68	28	4	7	...	107	4
5	September, 1901..	74	18	...	92	30	4	...	...	126	1
6	December, 1901...	70	2	14	86	30	4	5	...	125	...
	Totals.............	458	72	14	544	148	27	37	48	804	29

TABLE No. 2. — EXPENDITURES AND RECEIPTS ON ACCOUNT OF VOLUME XV, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1900-01.

Expenditures.		Receipts.	
Printing Journal	$1 848.88	Advertising	$2 338.00
Engraving, etc.	143.60	Sale of Journals	334.23
Postage on Journal	41.94	Sale of Reprints	30.20
Editor's Salary	475.00	Sale of Cuts	16.85
Advertising Agent, Com. .	244.35	Subscriptions	72.75
Copyright Fees	3.00		$2 792.03
Incidentals	36.76		
Reporting Meetings . . .	270.35		
Compiling Statistics, 1897-8-9	25.00		
Reprints of Papers	162.00		
Blank Forms for Statistics .	40.50	Excess of Expenditures . .	499.35
	$3 291.38		$3 291.38

TABLE No. 3. — Expenditures and Receipts on Account of the Journal of the New England Water Works Association, during 1901.

Expenditures.		Receipts.	
Printing Journal	$1 125.88	Advertising	$1 750.50
Engraving, etc.	78.40	Sale of Journals	315.68
Postage on Journal	31.94	Sale of Reprints	30.20
Editor	300.00	Sale of Cuts	16.85
Advertising Agent	244.35	Subscriptions	26.75
Copyright Fees	2.00		
Incidentals	13.25		
Reporting Meetings	151.00		
Reprints of Papers	105.00		
Blank Forms for Statistics	40.50		
	$2 092.32		
Excess of Receipts	47.66		
	$2 139.98		$2 139.98

As usual, fifty reprints of papers have been furnished to their authors without charge. Where a larger number were wanted, they have been supplied at cost. The expense to the Association for these reprints has averaged $4.69 for each paper.

The total cost of the illustrations for the volume has been $307.60, or 9.4 per cent. of the gross cost. This is somewhat less than in Volume XIV, where the percentage was 11.

The present circulation of the Journal is, —

Members	555
Subscribers	47
	602

Exchanges are made with fifteen periodicals.

As far as I know, there are no bills outstanding against the Association on account of the Journal.

TABLE No. 4.

Comparison between Volumes XIV and XV, Journal of the New England Water Works Association.

	Vol. XV Complete.	Vol. XV One Year.	Vol. XIV.
Edition (copies)	1 200	1 200	1 100
Numbers issued	6	4	4

Average membership..........	586	586	601
Pages of text	544	363	345
Pages of text per 1 000 members	926	618	600
Total pages, all kinds..........	804	536	485
Total pages per 1 000 members	1 370	913	832
GROSS COST:			
Total	$3 291.38	$2 194.26	$1 954.15
Per page...................	4.10	4.10	4.03
Per member	5.62	3.75	3.35
Per member, per 1 000 pages	6.99	6.99	6.91
Per member per 1 000 pages of text.........	10.31	10.31	9.71
NET COST:			
Total	$499.35	$332.90	$347.55
Per page	0.62	0.62	0.72
Per member	0.85	0.57	0.60
Per member per 1 000 pages	1.06	1.06	1.23
Per member per 1 000 pages of text.........	1.57	1.57	1.73

Respectfully submitted,

CHARLES W. SHERMAN,

Editor.

On motion of Mr. Cassell, it was voted that the report of the Editor be accepted and printed in the JOURNAL.

REPORT OF THE ADVERTISING AGENT.

The following report of Mr. Robert J. Thomas, Advertising Agent, was read by Mr. Sherman, Mr. Thomas being absent on account of illness.

LOWELL, January 1, 1902.

TO THE PRESIDENT AND MEMBERS OF THE NEW ENGLAND WATER WORKS ASSOCIATION:

Gentlemen, — I herewith present the annual report of the Advertising Agent for the year 1901: —

The last issue of the JOURNAL for 1900 contained the following advertisers: National Meter Co., 1 page; Hersey Mfg. Co., 1 page; Thomson Meter Co., 1 page; Union Water Meter Co., 1 page; Neptune Meter Co., ½ page; The Peck Bros. & Co., ½ page; Walworth

Mfg. Co., 1 page; Chadwick Lead Works, 1 page, Boston Lead Mfg. Co., ½ page; Lead-Lined Iron Pipe Co., ½ page; R. D. Wood & Co., 1 page; Sweet & Doyle, 1 page; Ludlow Valve Mfg. Co., ½ page; Emaus Pipe Foundry, ½ page; United States Cast-Iron Pipe and Foundry Co., 1 page; Warren Foundry and Machine Co., ½ page; M. J. Drummond & Co., ½ page; Builders Iron Foundry, 2 half-pages; New York Filter Mfg. Co., ½ page; E. P. Allis, 1 page; Perrin, Seamans & Co., ½ page; Gould Packing Co., ½ page; Lawrence Cement Co., ⅓ page; making a total of 16⅚ pages and an income of $1 135.

During 1901 the Edward P. Allis Co. and Sweet & Doyle refused to renew their advertisements, and the Boston Lead Mfg. Co. having been merged into the Chadwick-Boston Lead Works, another half-page was lost. With the foregoing exceptions all the advertisers renewed their contracts. The National Meter Co. increased their advertisement to 2 pages, the Neptune Meter Co. and the Lead-Lined Iron Pipe Co. increased their space from ½ page to a full page each, and the following new advertisers were added: The Sumner & Goodwin Co., 1 page; A. P. Smith Mfg. Co., ½ page; J. B. Campbell Brass Works, ½ page; Eddy Valve Co., ½ page; Kennedy Valve Mfg. Co., ½ page; Coffin Valve Co., ½ page; Rensselaer Mfg. Co., ½ page; B. F. Smith & Bro., ½ page; Barr Pumping Engine Co., 1 page; Eagle Oil and Supply Co., 1 page; International Steam Pump Co., 1 page; Jenkins Bros., 1 page; Garlock Packing Co., ½ page; National Paint and Varnish Co., ½ page; Boston Engineers' Supply Co., ½ page; A. W. Chesterton & Co., ½ page; Ashton Valve Co., ¼ page; Scannell & Wholey, ¼ page; Mason Regulator Co., ¼ page; and card advertisements from Davis & Farnum Mfg. Co., National Lead Co., and Thomas Watkins, making a total of 27⅓ pages, earning $1 929, an increase in revenue from this source of $794.

That this amount can be still further increased is true beyond doubt, for there are a number of manufacturers and dealers in water-works supplies that are not as yet among our advertisers, and this notwithstanding the efficiency of the JOURNAL as a medium for reaching the six hundred members of the Association, most of whom buy thousands of dollars worth of supplies every year. But the members must make it an object for advertisers. By this I mean that you should give them consideration when you are about to purchase, and give them an opportunity to submit prices, etc. It seems as

though every member who has the interests of the Association truly at heart should do this.

Of the many advantages and benefits that we have to offer to our members the JOURNAL is the greatest. To be sure, it is very enjoyable and instructive to attend our meetings in Boston and elsewhere, but later on if you want to profit by the papers you have heard here, you have to refer to the JOURNAL. Then, again, there is the twenty-five per cent. of the members who are too far away to attend these meetings, — those in New York, New Jersey, Canada, and other places, — all the benefit they receive is from the JOURNAL. Therefore, it is our duty to make the JOURNAL as able, thorough, and efficient as possible, and, in doing this, the income from the advertising will be a material aid.

Hoping that the number of advertisers will keep on increasing, and that those now advertising with us will find it profitable to continue, this report is respectfully submitted.

ROBERT J. THOMAS,
Advertising Agent.

THE PRESIDENT. The report of our Advertising Agent, with what has gone before it, shows conclusively that we made no mistake in the action taken at Rutland with regard to securing advertising matter for the JOURNAL. There are many of us who, earlier in life, have experienced the difficulty of inducing schoolboys or college boys to recognize the necessity and the propriety of contributing to the support of their school or college papers by patronizing the advertisers in them; but it would seem that with us older men it should not be necessary to lay so great stress upon the propriety and advisability of so doing.

On motion of Mr. Stacy, the report of the Advertising Agent was accepted and ordered to be printed in the JOURNAL.

ELECTION OF OFFICERS.

Mr. D. N. Tower, for the tellers of election, submitted the following report: —

Total number of votes, 168; 1 vote was blank, and 167 votes were cast for the official ballot as follows: —

President.

FRANK E. MERRILL, Somerville, Mass.

Vice-Presidents.

CHARLES K. WALKER, Manchester, N. H.
JAMES BURNIE, Biddeford, Me.
EDWIN C. BROOKS, Cambridge, Mass.
H. O. SMITH, Leicester, Mass.
WILLIAM B. SHERMAN, Providence, R. I.
J. C. HAMMOND, Jr., Rockville, Conn.

Secretary.

WILLARD KENT, Narragansett Pier, R. I.

Treasurer.

LEWIS M. BANCROFT, Reading, Mass.

Editor.

CHARLES W. SHERMAN, Boston, Mass.

Advertising Agent.

ROBERT J. THOMAS, Lowell, Mass.

Additional Members of Executive Committee.

PATRICK KIERAN, Fall River, Mass.
GEORGE A. STACY, Marlboro, Mass.
H. G. HOLDEN, Nashua, N. H.

Finance Committee.

A. W. F. BROWN, Fitchburg, Mass.
W. F. CODD, Nantucket, Mass.
J. W. CRAWFORD, Lowell, Mass.

The above-named gentlemen were declared elected. President Merrill was called to the chair by the retiring President, Mr. Crandall, and addressed the meeting as follows: —

Gentlemen, — In assuming the duties and responsibilities of the high office of President of the New England Water Works Association, I desire to take the opportunity to thank you heartily for the honor you have conferred upon me. I am sure that I shall have the cordial support which you have given to former presidents, and in return I pledge you my earnest efforts to do what I can to see that the Association does not fall from the high plane which it now occupies. [*Applause.*]

On motion of Mr. Coggeshall, the thanks of the Association were tendered to the retiring President and other officers.

Mr. Joseph E. Beals, Chairman of the Committee on Uniform Statistics, presented the report in behalf of that committee. A communication was read from Mr. M. N. Baker, and the committee was continued, with the addition of Mr. Baker and Mr. Charles W. Sherman as members, with instructions to make such further investigation as might be deemed expedient.

The discussion of the report of the Committee on Standard Specifications for Cast-Iron Pipe, presented at the December meeting, was continued by Mr. Leonard Metcalf and by Mr. Coffin and Mr. Brackett, members of the committee. Written discussions were also presented from the British Association of Water Works Engineers, Mr. George E. Manning, of New London, and others.

No action was taken upon the report of the committee.

Adjourned.

PROCEEDINGS.

FEBRUARY MEETING.

YOUNG'S HOTEL,
BOSTON, February 12, 1902.

President Frank E. Merrill in the chair.

The following members and guests were in attendance: —

MEMBERS.

L. M. Bancroft, Joseph E. Beals, James F. Bigelow, Dexter Brackett, E. C. Brooks, Fred Brooks, G. A. P. Bucknam, George Cassell, George F. Chace, John C. Chase, W. F. Codd, R. C. P. Coggeshall, M. F. Collins, L. E. Daboll, Charles R. Felton, R. J. Flinn, F. F. Forbes, William Paul Gerhard, H. F. Gibbs, J. C. Gilbert, Albert S. Glover, J. A. Gould, E. H. Gowing, William R. Groce, E. A. W. Hammatt, J. C. Hammond, Jr., George W. Harrington, D. A. Harris, L. M. Hastings, V. C. Hastings, T. G. Hazard, Jr., H. G. Holden, E. W. Kent, Willard Kent, C. F. Knowlton, James W. Locke, W. E. Maybury, F. A. McInnes, T. H. McKenzie, Thomas McKenzie, F. E. Merrill, G. L. Mirick, F. L. Northrop, W. W. Robertson, E. M. Shedd, Charles W. Sherman, J. E. Smith, Sidney Smith, J. A. St. Louis, G. A. Stacy, Robert W. Taber, C. N. Taylor, H. L. Thomas, R. J. Thomas, D. N. Tower, W. H. Vaughan, W. W. Wade, C. K. Walker, F. B. Wilkins, G. E. Winslow.

ASSOCIATES.

Harold L. Bond & Co., by Harold L. Bond; Builders Iron Foundry, by H. J. Burroughs and James Bowie; Charles A. Claflin & Co., by Charles A. Claflin; Coffin Valve Co., by H. L. Weston; Hersey Mfg. Co., by James A. Tilden and Albert S. Glover; Kennedy Valve Co., by M. J. Brosman; Lead-Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Co., by H. F. Gould and S. F. Ferguson; National Meter Co., by J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Perrin, Seamans & Co., by James C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; A. P. Smith Mfg. Co., by W. H. Van Winkle; Union Water Meter Co., by J. P. K. Otis, F. L. Northrop, and Charles L. Brown; United States Cast-Iron Pipe and Foundry Co., by John M. Holmes; R. D. Wood & Co., by Charles R. Wood.

GUESTS.

George H. Hart, Superintendent Water Works, Maynard, Mass.; George H. Partridge, *Engineering Record*, Boston, Mass.; George H. Leland, C. E., Providence, R. I.; John C. DeMello, Jr., New Bedford, Mass.; J. B.

Moore, Boston, Mass.; D. V. Macksey, Boston Water Works, Boston, Mass.; L. P. Stone, Natick, Mass.; Charles F. McCarthy, Worcester, Mass.; A. H. Robinson and E. L. Arundel, Water Commissioners, Lawrence, Mass.; W. Killan, Lawrence, Mass.; Clarence Goldsmith, North Andover, Mass.; John A. Connell, Charles A. Cook, J. Henry Gleason, H. J. Pratt, J. P. Wood, E. S. Murphy, H. C. Hunter, C. A. French, Louis P. Howe, E. Irving Sawyer, Walter P. Frye, O. H. Stevens, and Thomas P. Hurley, Water Commissioners and guests, Marlboro, Mass.

The Secretary read the following names of applicants for membership, the applications having been approved by the Executive Committee: —

For Resident Members.

Jeremiah H. Bartholomew, Ansonia, Conn.

A. M. Devereux, Castine, Me., Treasurer and Manager of the Castine Water Co.

Benjamin F. Goodnough, Brookline, Mass., Engineering Department Metropolitan Water Works.

Louis B. Cummings, Pittsfield, Mass., Clerk Board of Public Works.

George H. Hart, Maynard, Mass., Superintendent and Engineer of Maynard Water Works.

Andrew S. Merrill, Bath, Me., Superintendent Bath Division of Maine Water Co.

W. S. Wyman, Waterville, Me., Trustee Kennebec Water District.

Arthur B. Lisle, Providence, R. I., Treasurer of East Providence Water Co.

Edward Brown, Norfolk, Conn., Engineer and Superintendent Norfolk Water Co.

For Non-Resident Members.

William B. Fuller, Little Falls, N. J., Resident Engineer East Jersey Water Co.

William B. Brush, Brooklyn, N. Y., Civil Engineer.

For Associate.

The Thomas Hoey Supply and Manufacturing Co., Boston, Mill and Water Works Supplies.

On motion of Mr. Cassell, the Secretary was directed to cast one ballot in favor of the applicants, which he did, and they were declared elected members of the Association.

Mr. Charles W. Sherman, in behalf of the Boston Society of Civil Engineers, extended an invitation to the members of the Association to attend an informal meeting of the Boston Society, to be held in the evening, when Mr. F. E. Adams, of the Coffin Valve Co., would speak on "Essential Features of Gate Valve Construction."

Mr. George A. Stacy, Superintendent, Marlboro, Mass., then gave a description of the Marlboro Water Works, illustrating his remarks by stereopticon views.

Mr. Harry F. Gibbs, Engineer Water Works Pumping Station, Natick, Mass., read a paper entitled, "How to Obtain the Best Results in Small Pumping Stations." Mr. William F. Codd, Superintendent, Nantucket, Mass., followed with a short paper descriptive of a gasolene engine and its use as a reserve pumping plant in the Nantucket Works. Mr. D. N. Tower, Superintendent of the Cohasset Water Company, also spoke in regard to the Hornsby-Akroid kerosene oil engine in use at Cohasset.

Owing to the lateness of the hour, the further discussion of the report of the Committee on Standard Specifications for Cast-Iron Pipe was postponed to the next meeting.

Adjourned.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XVI. June, 1902. No. 2.

PRELIMINARY REPORT OF THE COMMITTEE ON STANDARD SPECIFICATIONS FOR CAST-IRON PIPE, WITH DISCUSSION.

FREEMAN C. COFFIN,* F. F. FORBES,† AND DEXTER BRACKETT,‡ *Committee.*

[*Report presented December 11, 1901; the discussions printed herewith include all those received up to May 1, 1902.*]

Mr. Freeman C. Coffin. Before reading this report, I will say that we hope that the report, or at least the specifications accompanying it, will not be considered by you as in their final form. The Committee, although it has met some of the representatives of the manufacturing interests, and also some others who are particularly interested in this subject, has not been able, even yet, to consider the matter in connection with others, and to discuss the points as it would have liked to do, simply on account of lack of time and press of other business. The specifications as they are presented to you now embody the present ideas of the Committee, and are presented with the hope that there will be a thorough discussion of all the points, and that a final form of the specifications may be adopted in view of all the discussion and suggestions and criticisms which may be made; and your Committee also thinks it may be desirable for the Association to communicate with other bodies which are considering this subject at the present time. The Committee hopes that the specifications will be fully discussed and criticised, so that all the points may be brought up.

(Mr. Coffin then read the report of the Committee and the proposed specifications, as follows): —

Boston, November 22, 1901.

To the New England Water Works Association:

Gentlemen, — In its consideration of this subject your Committee has assumed that it was your intention that its study should cover

* Civil Engineer, Boston, Mass. † Superintendent of Water Works, Brookline, Mass.
‡ Engineer Distribution Department, Metropolitan Water Works, Boston, Mass.

the design of cast-iron pipe and special castings, as well as the methods of their manufacture, and that its recommendations should include drawings of the pipes and special castings, tables of dimensions, and a list of weights for the different diameters and classes, in addition to specifications of the processes of manufacture and the character of the pipes when completed.

The Committee has conceived its duty to be not the recommendation of new processes, radical changes in existing specifications, nor even an unvarying list of weights for different heads or pressures, but rather a codification of the best present practice in design and manufacture in such form that, if used as a standard, pipe can be furnished by the manufacturers and procured by purchasers with more certainty of satisfaction than can be done at present, even with the most perfect individual specifications, and at the same time to be sufficiently elastic to allow, with a minimum of trouble, the incorporation of special ideas in an order for pipes.

It is believed that standard specifications to obtain general acceptance must allow for the personal equation of the user. While the many difficulties attending the present individualistic methods are well known, the Committee recognizes the futility of the adoption of a standard which, although securing uniformity, too closely limits individual freedom of practice.

The specifications recommended will not be wholly satisfactory to those who hope for an instrument which will of itself, without further thought or study, automatically regulate the whole business of securing suitable pipe for use under all conditions. The Committee believes, however, that it is practicable to arrange standards in such a manner that no one adopting them will be obliged to depart widely from his own practice, while at the same time many of the difficulties now attending the purchase and use of cast-iron pipes will be avoided.

SOME OF THE DIFFICULTIES OF PRESENT PRACTICE.

Form and Dimensions of Pipes and Castings. — The variation in form and dimensions of pipes and castings from different foundries, and even in different lots from the same foundry, causes much trouble and expense in pipe laying. Special castings are the most troublesome in this respect, spigots often being too large or thick to allow sufficient lead room in the bell of the pipe, even if they will enter at all without chipping the bead. Different classes of pipe

often cause trouble in the same way, especially when the different thickness of shell is secured by a change in the outside diameter.

Unless drawings are furnished for special castings (which it is not always practicable to do, especially for small orders), one does not know the length or weight, or even if the castings will come with bell and spigots, or bells all around. Sometimes reducers are sent with bells on the large end and sometimes on the small end. The radii of bends can rarely be ascertained in advance.

Even when drawings are furnished, unless an inspector is at the works, the castings are quite as likely to come of some other pattern and weight (not usually lighter), when the alternatives are to use those sent or wait for others to be cast and delivered.

On the other hand, it is clearly impossible for the manufacturer to keep a stock of pipe or specials on hand, when he cannot be sure that any two orders will have the same requirements, even in the simplest detail.

The entire lack of system in fixing the weights of pipes is the cause of much trouble and perplexity, the weight cards of the different foundries agreeing no better than the tables of different engineers. The great variety in specifications not only causes trouble in the foundry, but results to the purchaser of pipe not inspected at the works and of pipe in small lots or on quick orders, in the receipt of pipe which, although it may make fairly good work when laid, is nothing more nor less than a job lot of different sorts and sizes, very difficult to lay.

RECOMMENDATIONS.

In an endeavor to simplify and unify the practice in the manufacture and use of cast-iron pipes and special castings, your Committee makes the following suggestions, which are embodied in the appended *Standard Specifications for Cast-Iron Pipe*, which it recommends to the Association for adoption.

DESIGN.

Length. — The standard length of the pipes shall be 12 feet, exclusive of the bell or socket.

Diameters. — For sizes from 4 to 18 inches, inclusive, the inside diameter of pipes of a given nominal size shall be varied in accordance with the varying thickness used for different pressures or conditions, and the outside diameter for all classes or weights shall be

uniform. For sizes larger than 18 inches, there shall be three sizes for the outside diameter of each nominal diameter.

It is feared that if one outside diameter were adopted for all classes in the larger sizes of pipes, it would cause so much difficulty in connecting future pipe to that already laid, and in making repairs, that it would be a serious obstacle to the adoption of the standard. It is also believed that the use of more than one outside diameter will not cause so much trouble in the larger sizes as in the smaller ones.

The Committee has endeavored to suggest outside diameters for the several sizes of pipes that will conform as nearly as possible to sizes in general use at the present time, and, also, those which will give the full interior diameter for the thickest pipe in common use. The outside diameters proposed by the Committee are given in Table No. 1 of the specifications.

Depth and Joint Room of Bells. — There is undoubtedly considerable variation in present practice in the depth of bells. The Committee is of the opinion that good results are secured with all depths used, and that an exact depth of bell is not an essential matter to any engineer. Therefore, as the use of a standard bell will do much to simplify the casting of pipe, it recommends the adoption of the list of depths given in Table No. 1. These depths are believed to conform very nearly to the average practice.

Although the practice regarding variation in joint room is not as great as in the depth of the bells, the Committee was influenced by the same reasons to recommend a uniform list of thickness, which is also found in Table No. 1.

If Table No. 1 is adopted as the standard, and adhered to, the result will be that every pipe and special casting under 20 inches in diameter will fit every other pipe and casting of the same nominal size.

Thickness and Weight of Pipe. — In the classification of cast-iron pipe for different pressures and conditions is to be found a more serious divergence of opinion and practice than in any other branch of the subject. The Committee has not deemed it advisable to recommend the adoption of standard weights for stated pressures for the reason that the thickness or weight of the pipe to be used depends in many cases upon other conditions in addition to the static pressure. In pipes of the smaller sizes the thickness required depends upon the strength needed to withstand handling and the strains

due to the settlement of earth, and other causes, rather than upon the internal pressure. For this reason heavier pipes are required in city streets, where they are subjected to settlement from frequent excavations, than in country towns where they remain undisturbed.

Other conditions beside the pressure must also be considered in determining the thickness of the large sizes of pipe ; for example, large pipes in public streets, where they may be subject to heavy loads, or in places where the depth of earth covering is great, should be made thicker than where laid in locations specially reserved for their use. The static head or pressure can be closely estimated, but the water hammer, effect of traffic over the pipe, settlement under it, tuberculation within it, electrolysis outside of it, and age everywhere, can, with present knowledge, be given no mathematical value. These conditions must, however, be taken into consideration in determining the thickness of pipe to be used in any given case.

It is probable that no formula exists which is a scientific expression of all these requirements — perhaps no such rational formula can be devised, certainly not until more definite data are secured for the various strains, both internal and external, which are sustained by pipes in use. It was finally decided to devise a table of thicknesses and weights based upon some logical formula, and to give the different weights an arbitrary classification denoted by a symbol such as a letter of the alphabet, in which the variation in weights from one class to another should not be so great that one would be unable to select pipes that would approximate his own practice and of sufficient range to cover all except the most extreme cases.

The thicknesses given in Table No. 2 were computed by the following formula, which is one used in determining the thickness of pipe used on the Metropolitan Water Works, which supply water to Boston and other cities and towns within a radius of ten miles; Class A being for a static head of fifty feet, Class B for one hundred feet, etc., each class advancing by fifty feet. This formula provides factors for the deterioration of the pipe by time and other conditions, for the internal strain due to the static head and to water hammer, but, as has been previously stated, other conditions must also be considered.

$$t = \frac{(p + p')r}{3300} + 0.25 \text{ in which}$$

t = thickness in inches;

p = static pressure in pounds per square inch;

p' = pressure in pounds allowed for water hammer;

r = internal radius of pipe in inches;

3 300 = 1/5 tensile strength of cast iron taken to be 16 500 pounds per square inch;

0.25 = allowance for deterioration by corrosion and other causes.

VALUES GIVEN TO P′ AS FOLLOWS:

Diameter of Pipe.	*P′ in Pounds.*
4, 6, 8, and 10 inch.	120
12 and 14 inch.	110
16 and 18 inch.	100
20 inch.	90
24 inch.	85
30 inch.	80
36 inch.	75
42 to 60 inch.	70

The Committee does not recommend the classification of the weights upon the basis of static head, believing that to the engineer or superintendent should be left the final decision as to the thickness or weight of pipe suitable for the particular place in which it is to be used.

Table No. 2, if adopted, will furnish a basis for pipe practice in which the classes will have a uniform meaning, and when used as the basis of an order will insure to the buyer the pipe which he intends to use. This will be a distinct improvement on present conditions under which a class letter has no meaning, except when accompanied by a statement of weight.

The table does not assume to fix the weight which shall be used for different heads or conditions of service. It is believed that the range is sufficient to provide for all usual conditions, and that the variation between one class and the next is not great enough to prevent the selection of weights that will closely approximate individual practice.

This uniform classification does not necessitate any radical departure from present foundry methods, yet it can hardly fail to be of advantage to the pipe manufacturer, especially in providing standard weights for stock pipe.

Special Castings. — In general design, the special castings recommended are of the pattern now used on the Metropolitan Water Works. A number of foundries have the patterns for these castings, and they are already in a fair way to become a standard.

The Committee is of the opinion that it would be difficult to improve upon these patterns. They are designed with the purpose of

putting as little metal into the special castings (where it costs about twice as much as it does in straight pipe) as is consistent with strength and convenience in laying.

As the specifications allow a margin for excess or deficiency in weight of not exceeding six per cent., abnormal excess of weight (a serious fault in many castings) is avoided, and the purchaser can estimate with reasonable accuracy the cost of the castings in advance.

The outside diameter and the openings of the bell or socket are the same as those of the pipes of the same size. There is but one class of special castings for all classes of pipe below twenty inches. It is hoped that the vexing occurrence of the necessity for chipping spigots of special castings to enable them to enter the pipe bells, which has heretofore been much too common, will be avoided by this uniformity.

Tables giving full dimensions and weights will accompany the specifications in their final form.

Manufacture.—The clauses of the specifications which refer to the processes of the manufacture of the pipe and castings are recommended by the Committee as representing in its opinion the best modern practice which has been tested by time and experience.

There are some points which are as yet unsettled, such, for instance, as the coating of the pipes. The Committee believes that the method specified is the most satisfactory one in general use. It recognizes, however, that improvement in this matter is to be desired. It is possible that some of the processes already suggested may prove to be better. They are yet in the experimental stage, and, therefore, not suitable subjects for recommendation. Even standard specifications must be subject to revision, as experience shows their requirements to be rendered obsolete by better methods. It is, of course, always open to the purchaser to substitute requirements of his own for any clause or clauses of the specifications or in addition thereto. The fact that he may often choose to do so does not impair the value of standard specifications.

In conclusion, the Committee will state that the specifications are recommended to the Association for criticism and amendment, if thorough discussion by all interested shows changes to be desirable.

Respectfully submitted,

FREEMAN C. COFFIN,
F. F. FORBES,
DEXTER BRACKETT,

Committee on Standard Specifications for Cast-Iron Pipe.

SPECIFICATIONS.

DESCRIPTION OF PIPES.

The pipes shall be made with hub and spigot joints, which shall accurately conform to the dimensions given in Table No. 1.

They shall be true circles in sections, with their inner and outer surfaces concentric.

The straight pipes shall be straight, and the curved pipes shall be true to the required curvature in the direction of their axes.

They shall be of the specified dimensions in internal diameter from end to end, and the straight pipe shall be twelve feet in length, exclusive of socket.

Especial care shall be taken to have the sockets of the required size. The sockets and spigots will be tested by circular gages, and no pipe will be received which is defective in joint-room from any cause. The joint-room for each class of pipe shall not vary more than .06 of an inch from the dimensions given in Table No. 1.

No pipe shall be accepted when the thickness of metal in the body of the pipe is more than .08 of an inch less at any point than the standard thickness given in Table No. 2.

The length of the pipe shall not be changed except by written permission of the engineer, and in case of such change the standard weight of the pipe given in Table No. 2 shall be modified in accordance therewith.

DEFECTIVE SPIGOTS.

Defective spigot ends on pipes twenty inches or more in diameter may be cut off in a lathe, and a half round wrought-iron band shrunk into a groove cut in the end of the pipe. Not more than six per cent. of the total number of accepted pipes of each size shall be cut and banded, and no pipe shall be banded which is less than eleven feet in length, exclusive of the socket.

SPECIAL CASTINGS.

All special castings shall be made in accordance with the cuts and the dimensions given in the tables forming a part of these specifications.

The flanges on all manhole castings and manhole covers shall be faced true and smooth, and drilled to receive bolts of the sizes given in the tables. The contractor shall furnish and deliver all bolts for

bolting on the manhole covers, the bolts to be of the sizes shown on plans, and made of the best quality of American refined iron, with hexagonal heads and nuts, and sound, well-fitting threads.

MARKING.

Every pipe and special casting shall have distinctly cast upon it the initials of the maker's name, the year in which it was cast, and the class letter. When cast especially to order, each pipe and special casting shall also have cast upon it the number signifying the order in point of time in which it was cast, the figures denoting the year being above and the number below; thus: —

1901,	1901,	1901,
1	2	3

etc., also any initials, not exceeding four, which may be required by the purchaser.

The letters and figures to be cast on the outside, not less than two inches in length and one eighth of an inch in relief.

PERCENTAGE TO BE PAID FOR.

No pipe shall be accepted the weight of which shall be less than the standard weight by more than four per cent. for pipes 16 inches or less in diameter, three and one-half per cent. for 18-, 20-, and 24-inch pipes, and three per cent. for pipes more than 24 inches in diameter; and no excess above the standard weight of more than the given percentages for the several sizes shall be paid for. The total weight to be paid for shall not exceed for each size and class of pipe the sum of the standard weights for the same number of pieces of the given size and class by more than two per cent.

No special castings shall be accepted the weight of which is more than six per cent. less than the standard weight, and not more than six per cent. in excess of the standard weight shall be paid for.

QUALITY OF IRON.

The metal shall be made without any admixture of cinder iron or other inferior metal, and shall be remelted in a cupola or air furnace. It shall be of such character as to make a pipe strong, tough, and of even grain, and soft enough to satisfactorily admit of drilling and cutting.

Specimen bars of the metal used, each being 26 inches long by 2 inches wide and 1 inch thick, shall be made without charge as often as the engineer may direct. The bars, when placed flatwise upon supports 24 inches apart and loaded in the center, shall support a load of 2 000 pounds, and show a deflection of not less than .35 of an inch before breaking. Should the dimensions of the bars differ from those above given, a proper allowance therefor shall be made in the results of the tests.

HOW CAST.

The straight pipes shall be cast in dry sand molds, in a vertical position, with the hub-end down, and the special castings in loam, except when otherwise permitted in writing, in either case, by the engineer.

The pipe shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal contraction by subsequent exposure.

QUALITY OF CASTINGS.

The pipes and castings shall be smooth, free from scales, lumps, blisters, sand holes, and defects of every nature. No plugging or filling will be allowed.

CLEANING AND INSPECTION.

All pipes and special castings shall be thoroughly cleaned and subjected to a careful hammer inspection. No casting shall be coated unless entirely clean and free from rust, and approved in these respects by the engineer immediately before being dipped. The contractor shall provide a covered tramway from the casting-room to the dipping vat, so that no casting shall be liable to become wet previous to its being coated.

COATING.

Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle, nor with any tendency to scale off.

Each casting shall be heated to a temperature of 300 degrees Fahrenheit immediately before it is dipped, and shall possess not

less than this temperature at the time it is put in the vat. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

The varnish shall be heated to a temperature of 300 degrees Fahrenheit (or less, if the engineer shall so order) and shall be maintained at this temperature during the time the casting is immersed.

Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated, the pipes shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be recoated shall first be thoroughly scraped and cleaned.

HYDROSTATIC TEST.

When the coating has become hard, the straight pipes shall be subjected to a proof by hydrostatic pressure, and, if required by the engineer, they shall also be subjected to a hammer test under this pressure.

The pressures to which the different sizes and classes of pipes shall be subjected are as follows: —

Class	A	pipe,	150	pounds	per	square	inch.
,,	B	,,	200	,,	,,	,,	,,
,,	C	,,	250	,,	,,	,,	,,
,,	D	,,	300	,,	,,	,,	,,
,,	E	,,	350	,,	,,	,,	,,
,,	F	,,	400	,,	,,	,,	,,

They shall also be subjected to the same proof by water pressure and hammer test after their delivery and before their final acceptance, if required by the engineer.

WEIGHING.

The pipes and special castings shall be weighed for payment under the supervision of the engineer, after the application of the coal-tar pitch varnish, and the weight of each pipe and special casting shall be conspicuously painted in white on the inside, after the coating has become hard. If desired by the engineer, the pipes and special cast-

ings shall be weighed after their delivery, and the weights so ascertained shall be used in the final settlement.

CONTRACTOR TO FURNISH MEN AND MATERIALS.

The contractor shall provide all tools, materials, and men necessary for the proper testing, inspection, and weighing at the foundry of the pipes and special castings; and if required by the engineer, he shall furnish a sworn statement that all of the tests have been made as specified, this statement to contain the results of the transverse tests upon the test bars.

POWER OF THE ENGINEER TO INSPECT.

The engineer shall be at liberty at all times to inspect the material at the foundry, and the molding, casting, and coating of the pipes and special castings. The forms, sizes, uniformity, and conditions of all pipes and other castings herein referred to shall be subject to his inspection and approval, and he may reject, without proving, any pipe or other casting which in his opinion is not in conformity with the specifications or drawings furnished. He shall have the power to prevent the use of any metal, mold, or core which in his opinion may not be proper for the purpose for which it is intended.

CASTINGS TO BE DELIVERED SOUND AND PERFECT.

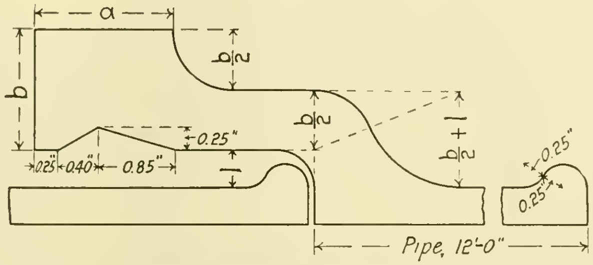
All the pipes and other castings must be delivered in all respects sound and conformable to these specifications. The inspection shall not relieve the contractor of any of his obligations in this respect, and any defective pipe or other casting which may have passed the engineer at the works or elsewhere shall be at all times liable to rejection when discovered, until the final completion and adjustment of the contract. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material of any kind shall be placed in the pipes during transportation or at any time after they receive the coating.

DEFINITION OF THE WORD "ENGINEER."

Wherever the word "engineer" is used herein it shall be understood to refer to the engineer, or inspector, acting for the purchaser, and to his properly authorized agents, limited by the particular duties intrusted to them.

Table No. 1

General Dimensions of Pipes and Special Castings.



Nominal Diam. Inches	Class	Actual Outside Diam. Inches	Depth of Sockets Pipe. Inches	Depth of Sockets Special Castings. Inches	Thickness of joint for calking.– Inches	"a"	"b"
4	All Classes	4.90	3.00	4.00	.40	1.50	1.30
6	" "	7.00	"	"	"	"	1.40
8	" "	9.10	3.50	"	"	"	1.50
10	" "	11.30	"	4.50	"	"	1.50
12	" "	13.40	"	"	"	"	1.60
14	" "	15.50	"	"	"	"	1.70
16	" "	17.60	4.00	5.00	.50	1.75	1.80
18	" "	19.70	"	"	"	"	1.90
20	Classes A&B	21.30	"	"	"	"	2.00
"	" C-D	21.60	"	"	"	"	"
"	" E-F	21.80	"	"	"	"	"
24	" A-B	25.40	"	"	"	2.00	2.10
"	" C-D	25.80	"	"	"	"	"
"	" E-F	26.10	"	"	"	"	"
30	" A-B	31.60	4.50	"	"	"	2.30
"	" C-D	32.00	"	"	"	"	"
"	" E-F	32.40	"	"	"	"	"
36	" A-B	37.80	"	"	"	"	2.50
"	" C-D	38.30	"	"	"	"	"
"	" E-F	38.70	"	"	"	"	"
42	" A-B	44.00	5.00	"	"	"	2.80
"	" C-D	44.50	"	"	"	"	"
"	" E-F	45.10	"	"	"	"	"
48	" A-B	50.20	"	"	"	"	3.00
"	" C-D	50.80	"	"	"	"	"
"	" E-F	51.40	"	"	"	"	"
54	" A-B	56.40	5.50	5.50	"	2.25	3.20
"	" C-D	57.10	"	"	"	"	"
"	" E-F	57.80	"	"	"	"	3.80
60	" A-B	62.60	"	"	"	"	3.40
"	" C-D	63.40	"	"	"	"	"
"	" E-F	64.20	"	"	"	"	4.00

Table No. 2

Standard Thickness and Weight of Cast Iron Pipe.

12 feet in length exclusive of socket.

Nominal Diameter of Pipe Inches	Class A		Class B		Class C		Class D	
	Thickness of shell Inches	Weight per Length	Thickness of shell. Inches	Weight per Length.	Thickness of shell Inches	Weight per Length.	Thickness of shell. Inches	Weight per Length
4	.34	200	.35	207	.36	212	.38	218
6	38	330	.40	340	.42	355	.44	370
8	.42	475	.45	500	.48	525	.50	550
10	.47	650	.50	685	.53	725	.56	765
12	.49	810	.53	865	.57	920	.61	980
14	.53	1010	.57	1085	.61	1155	.66	1230
16	.55	1215	.60	1310	.65	1410	.70	1500
18	.57	1410	.63	1540	.69	1660	.75	1790
20	.60	1610	.66	1760	.72	1920	.79	2080
24	.64	2050	.72	2290	.80	2530	.88	2770
30	.71	2860	.81	3230	.91	3600	1.01	3950
36	.79	3800	.90	4270	1.02	4830	1.13	5300
42	.87	4900	1.00	5560	1.13	6270	1.27	6970
48	.95	6130	1.10	6970	1.25	7900	1.40	8780
54	1.03	7510	1.20	8600	1.37	9800	1.54	10900
60	1.10	8900	1.30	10300	1.50	11900	1.70	13300

Nominal Diameter of Pipe. Inches	Class E		Class F		Class G	
	Thickness of shell. Inches	Weight per Length	Thickness of shell. Inches	Weight per Length	Thickness of shell. Inches	Weight per Length
4	.39	225	.40	230	.42	240
6	.46	385	.48	400	.50	415
8	.53	575	.56	600	.58	630
10	.60	805	.63	845	.67	885
12	.65	1035	.69	1090	.73	1150
14	.70	1300	.75	1380	.79	1450
16	.75	1600	.80	1700		
18	.80	1910	.86	2040		
20	.85	2250	.92	2410		
24	.95	3000	1.03	3240		
30	1.10	4320	1.20	4680		
36	1.25	5900	1.37	6360		
42	1.40	7700	1.53	8350		
48	1.55	9740	1.70	10600		
54	1.72	12350	1.90	13500		
60	1.90	15100	2.10	16500		

DISCUSSION.

Mr. Coffin. As it is desirable to have a full discussion here by all who are interested, and as all who have received the advance copy of the report have been invited to discuss it either by letter or orally; and as there is, I believe, a clause in the by-laws or constitution which requires some action of the Association in relation to discussion by others than members, it may be in order for me to make a motion that this discussion be open to all who are interested in the subject.

Adopted.

The Chairman. The matter is now open for discussion. I think we would like to hear from the other members of the Committee, and I will call upon Mr. Brackett.

Mr. Dexter Brackett. It seems to me, Mr. Chairman, that the Committee having presented its report, the members should now discuss the subject, and if any questions arise I shall be very glad to explain my position on the subject. The report of the Committee contains my ideas, subject to revision, as suggestions may be made by the members.

Mr. Emil L. Nuebling* (by letter). The Committee on Standard Specifications for Cast-Iron Pipe has made a move in the right direction by recommending that the outside diameters shall be made uniform for all classes of pipes under twenty inches in diameter, and would not have been severely censured if this practice had been extended to include all sizes of pipes. Standard sizes, to be perfect, should not be burdened with several subdivisions, and so long as there are several standard sizes of pipe for one nominal diameter, the general adoption of the standard specifications will not take place. The benefits to be derived by the adoption of a single standard greatly outweigh the objections to it. If the standard outside diameter is proportioned by the formula given by the Committee (making p equal 120 pounds per square inch) it will conform to the bulk of the pipes in use at the present time. The objection made by the committee, that it would cause much difficulty in connecting future pipes to those already laid, can be readily overcome by the use of a casting of short length, having a standard spigot on one end and a bell or hub on the other end large enough to go over the old style of pipe. The benefits of a single standard are many, to manufacturers as well

* Engineer and Superintendent of Water Works, Reading, Pa.

as users. If a standard were in universal use, the manufacturers of pipe would be saved the expense of providing many different sizes of pipe patterns, and this might eventually result in the general introduction of the rotary mold ramming machine, which will give better workmanship at less cost. Manufacturers of gates, fire hydrants, and special castings will be equally benefited with the pipe manufacturers by using a single pattern for all bells and hub ends. The single standard will also save carrying a miscellaneous lot of gates and specials on hand, having different sizes of bell openings, in localities where all the different classes of pipes would be in use. A special or gate made for a 48-inch Class E pipe would not be used on a Class B pipe, because the lead joint would be 1.1 inches thick, which is entirely too large for good work; so, to be prepared for any emergency, several specials or gates of each nominal diameter above eighteen inches would have to be kept in stock if the multiple standard is used.

The standard thickness of joints for calking should be made as small as possible, having no greater thickness of lead than is absolutely necessary for proper pouring and calking of joints. The strength of lead joints varies directly as their thickness. A joint $\frac{1}{4}$ inch in thickness is as strong again as a joint $\frac{1}{2}$ inch in thickness, because the larger joint has so much more area exposed to the pressure of the water back of it. We have laid several thousand feet of 36-inch pipe with lead joints $\frac{3}{8}$ inch in thickness, and have had no leaks on this line since it was laid, several years ago; while a line of 24-inch and 30-inch pipes with joints of from $\frac{5}{8}$ to $\frac{3}{4}$ inch in thickness is giving us very much trouble from leaks caused by the lead joints pushing out. With the merit of small joints in mind, the following suggestion is made: That the thickness of joints for calking be made $\frac{5}{16}$ inch for all sizes of pipes from 4 inches to 20 inches inclusive, $\frac{3}{8}$ inch for sizes from 24 inches to 42 inches inclusive, and $\frac{7}{16}$ inch for sizes from 48 inches to 60 inches inclusive.

Mr. Frank A. McInnes* (by letter). I have read with pleasure the able report of the Committee on Standard Specifications; its adoption would prove a long step in the right direction, to the advantage of consumer and manufacturer alike. The requirement of a uniform outside diameter is a wise innovation in general practice; it was adopted by the Boston Water Department three years ago, and since that time there has been a gratifying absence of the necessity

* Assistant Engineer, Engineering Department, City of Boston.

of chipping beads, and abnormally large or small joints have disappeared. One criticism, perhaps a somewhat selfish one, suggests itself, viz., in regard to the depths of bell; those proposed are, in my opinion, too shallow for pipe which is to be laid in the streets of a city where the danger of disturbance and settlement is ever present: our streets are so filled with pipes, conduits, tubes, etc., of all kinds, that we are forced to depend upon "open joints" in addition to "specials," to solve some of our problems.

There are two possible additions to the specifications which I would like to suggest, for discussion at least. The first is the insertion of a clause regarding chemical analysis: this is a feature in specifications for steel and wrought iron — why not apply it to cast iron? My attention was particularly called to this point by a succession of breaks in a 48-inch line (laid in 1869) which could not be satisfactorily explained; a chemical analysis, made in the case of each break, conclusively stamped the iron as "bad." It is conceivable that test bars might not have condemned this iron, as they are not infallible, particularly when their pouring and cooling are not closely watched; the pressure test, too, might easily fail in the case of brittle iron. A requirement stipulating the composition of the metal would be getting at the very foundation; it, of course, would not take the place of the test bar, but it might be employed occasionally to great advantage, at any time before the final payment. The very fact of the existence of such a clause in the specifications would be useful.

The second suggestion is the desirability of requiring that certain castings, such as $\frac{1}{8}$ and $\frac{1}{16}$ bends, branches, reducers, hydrants, etc., be made with green-sand cores. The principal advantage in this method of casting is in the fact that chaplets are not used; the arbor around which the core is formed passes out through the flask, and is held rigidly in place without further assistance. I think it will be granted that the chaplet is apt to be the weakest spot in a casting — a collection of them made during the past summer from our junk pile would convince the doubter of this fact. Another advantage of the green-sand method is that it is easier to get smooth, uniform castings in this way than with dry-sand cores. The method is applicable to castings up to twenty inches in diameter at least. For the past year, the bends (except quarter turns), the branches, reducers, sleeves, etc., (under 24-inch), and the hydrants used by the Boston Water Department have been made in green sand with marked success.

There is a further inviting field for investigation, namely, the

actual structure of the iron as disclosed by the microscope and by photography. Before long we will have to consider this feature in our specifications.

Mr. Louis H. Knapp* (by letter). I approve of Tables No. 1 and 2 in every respect, and think it very desirable to have them adopted.

The following clauses from the Buffalo specifications may be of interest: —

4. All pipes shall be cast vertically, and shall be made in such molding sand or loam as will leave the surface in good condition to receive the coal-tar varnish.

5. The metal of which the pipes are made shall be iron, remelted in a cupola or air furnace, and of such make as shall be approved by the engineer.

It shall be without any admixture of cinder iron or inferior metal, entirely free from uncombined carbon, when seen under the microscope, and shall admit of being easily drilled or cut. The iron in the pipe shall have a tensile strength of at least eighteen thousand (18 000) pounds to the square inch.

I think some reference should be made to the quality of the sand; also. the tensile strength of the cast iron should be specified.

I would leave out the clause relating to defective spigots in the general specifications, and leave the question of defective ends to the engineer or inspector.

13. Every pipe shall be carefully coated inside and out with coal-tar pitch and oil, in accordance with the following rules: —

Every pipe must be thoroughly dressed and made clean, free from the earth or sand which clings to the iron in the mold.

Every pipe must be entirely free from rust and dust when the coating is applied. If the pipe cannot be dipped immediately after being cleaned, the surface must be oiled with linseed oil to preserve it until it is ready to be dipped; no pipe to be dipped after the rust has set in.

The coal-tar pitch is to be made from coal tar, distilled until the naphtha is entirely removed and the material deodorized. It should be distilled until it has about the consistency of wax when cold. The mixture of five or six per cent. of linseed oil is recommended. Pitch which becomes hard and brittle when cold will not answer.

Pitch of the proper quality, having been prepared, must be carefully heated in a suitable vessel to a temperature of 300 degrees Fahrenheit, and be maintained at not less than this temperature during the time of dipping. The material will thicken and deteriorate after a number of pipes have been dipped; fresh pitch must, therefore, be added from time to time, and occasionally the vessel must be entirely emptied of its contents and refilled with fresh pitch; the refuse will be hard and brittle, like common pitch.

Every pipe must attain a temperature of 300 degrees Fahrenheit before it is removed from the bath. It may then be removed and laid upon skids to drip.

Pipes of twenty inches diameter and upwards will require to remain at least thirty minutes in the hot fluid to attain this temperature, probably more in cold weather.

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* Engineer, Buffalo Water Works.

The application must be made to the satisfaction of the engineer, and the material and process be subject at all times to his examination, inspection, and approval.

I would not require the castings to be heated to 300 degrees before dipping, but would require them to obtain that temperature in the vat.

The hydrostatic test should be as you have it, and not for a general pressure of three hundred pounds for all pipes.

In general the specifications as you have reported are a great improvement and advance over what has been used in the past. As a whole I am in favor of them.

R. D. Wood & Co.* (by letter). With your esteemed favor of December 4 to Mr. Walter Wood, we received the copies of report of Committee of the New England Water Works Association on Standard Specifications, showing the suggested form for such specifications. We at once referred it to our foundrymen, and communicated with other pipe foundries. As yet we are unable to get satisfactory or complete reports as to how much the various changes would affect the expense and trouble of making pipe and specials. This extra cost would eventually, of course, be borne by the buyers, and would be a disadvantage to all foundries. There are some details which, for the mutual interests of water works and pipe makers, should be modified, — to what extent we cannot state until we can get an agreement with other foundries as to what would be a fair average of the several interests. Unfortunately, in the short time we have had the pamphlet, this has not been practicable, and we trust that no final action may be taken until we can meet your Committee with a full statement of our ideas on the several changes.

The Chairman. We have a representative of the United States Pipe Foundry here, Mr. Lemoine, and we would like to hear from him.

Mr. L. R. Lemoine. I do not know that there is very much that I can say on behalf of the manufacturers, because, as has been intimated in the letter just read, we have not had an opportunity of getting together. I can say on behalf of our own company, however, that a glance at these specifications indicates that there are a number of points in them which, from a manufacturer's standpoint, we think it would be to the interest of your Association to have carefully considered before they are incorporated in the final report. I have

* Pipe Founders, Philadelphia, Pa.

spoken to Mr. Brackett in regard to the matter to-day, and I will venture to refer to just one item. It is stated in one clause here that special castings must all be made in loam. That matter has been mentioned in one of the papers which has been read, — I think it was in Mr. McInnes'. Now, the general practice at most foundries, I think I am safe in saying, is that upwards of three fourths, if not four fifths of the special castings are made in green sand; and as the specials grow larger the practice in making them varies from green sand to a combination of dry sand and loam, and then loam. The practice also varies with the number of specials of a particular kind. For instance, take a 48-inch, $\frac{1}{16}$ bend; if only one is required for a certain dimension it may be cheaper to sweep it up. On the other hand, if there are fifty or sixty of them, it may be cheaper to make them in a combination of dry sand and loam, or entirely in dry sand, depending somewhat on the radius of the bend.

There are a great many items in the proposed specifications which I am sure the Committee will permit us at least to point out to them, which make it seem best, if the Association agrees with us, to have this matter referred back to the Committee, and ask them at their convenience to confer with the manufacturers — after giving the manufacturers a chance to confer among themselves; for I presume the Committee would like to have the manufacturers fully agreed before meeting them.

The Chairman. Before we have a discussion by any users of pipe, if there are any other representatives of pipe foundries here, we would like to hear from them.

Mr. Edmund F. Krewson. Mr. President and gentlemen, I represent R. D. Wood & Co. Mr. Lemoine has expressed our position quite fully. We are in hearty sympathy with this movement, and we realize the intelligence and care with which these specifications have been prepared; and yet we are unprepared to accept them until these matters, some of which Mr. Lemoine has indicated, are more thoroughly threshed out among the foundrymen. We have tried to get together, but we have been delayed. We think, however, in a short time we will be able to make such a presentation to your Committee as will be mutually satisfactory. We have no items to suggest now, being comparatively unprepared. I can therefore simply endorse Mr. Lemoine's position and say that we would like an extension of time.

Mr. Coffin. I believe Mr. Edwards, who represents the Montreal

Pipe and Foundry Company of Canada, is here, and I should like to hear from him.

Mr. Edwards. I regret to say, Mr. President, that I have not the honor to be a member of the Association, but I have come here in response to the general invitation which is extended with the advance copy of the Committee's report. I might say that our views would be very much in line with those which have been expressed by previous speakers representing the manufacturers, namely, that there are many points here which ought to be handled with considerable care, and awaiting, possibly, the decision of the manufacturers.

If you will permit me, I will run over some of the matters mentioned in this printed draft of the report. In the first place, I would say, that the company which I represent probably differs from the larger companies in the United States, in that we make chiefly small pipe. We make mostly 6-inch, 8-inch, 10-inch, and 12-inch. While we have facilities for making the larger pipe, still 24-inch is the maximum size that we usually make. What I shall say, therefore, will have reference chiefly to small pipe.

The questions of joint room, and such matters, are ordinarily in the hands of the engineers, and they do not matter very much to the manufacturer, so far as I judge.

In connection with the percentage of accepted pipes which have cut ends, I notice it says that "no pipe shall be banded which is less than eleven feet in length, exclusive of the socket," and "not more than six per cent. of the total number of accepted pipes of each size shall be cut and banded." I presume that refers to pipes twenty inches or more in diameter, but by inference it would cover all classes of pipe. I should think, from the manufacturers' standpoint, that ten per cent. of cut ends would be a fair allowance, because fully that number are turned out from the average factory, and if only six per cent. were accepted it would throw a considerable percentage upon the manufacturers. I know the custom with us has been to include ten per cent., and in most cases that has been acceptable.

Then, as regards marking. The class letter is a point that is rather hard on the manufacturers, because in casting it is impossible to get the weights of pipe within the limits of the class provided in these specifications; and if a pipe were branded with a certain class letter, in case the weight limit was not reached or was exceeded, it would be branded in the wrong class, and would be rather bad stock

in the hands of the manufacturer. He would have to chip the class letter off and paint on a new one, which would rather detract from the value of the pipe. It seemed to me that the class letter could be very well left out, in the interest of the manufacturers.

And, also, the number signifying the order in point of time in which the pipe is cast is a point. While it is undoubtedly valuable to the engineer to know the running number of his pipes, still the pipe might be thrown back on the hands of the manufacturer through the clause which usually permits the engineer to decrease the contract by, say, twenty per cent.; and a pipe which was thrown back upon the hands of the manufacturer, bearing a certain number cast on it and also a class letter, would be dead stock, or stock for which there would certainly be but a limited demand.

Then, again, in small pipe, — and I am referring to small pipe especially, — the question of casting with hub end or bell end down, judging from the literature that is to be had in regard to the casting of pipes, is a matter on which there is a wide divergence of opinion at present; but these specifications would call for all pipes, no matter how small, to be cast with the bell end down. I know that the three factories which I represent have a large plant for casting with the bell end up, and to make a change would necessitate the incurring of considerable expense.

Special castings to be cast in loam is another feature, which a previous speaker has touched on. I know in our case green sand is used almost entirely for small castings.

On the question of hydrostatic test, it is provided in the specifications that all pipes in Classes E and F are to have, respectively, a pressure of 350 and 400 pounds per square inch. Now, applying that to the smaller sizes of pipes, the 4-inch and 6-inch, and even 8-inch pipe, even with the thickness provided for these respective classes, it is a very heavy pressure on pipe for purposes of testing in the foundry; and it seemed to me that a change to the effect that pipes, say under twenty inches, need not be tested to a higher figure than 300 pounds would cover the ground very well. According to this, a 4-inch pipe in Class G only runs twenty pounds to the foot, which is a fair average weight from previous practice, and that would be subject to a test of 400 pounds to the square inch.

That brings up the question of the weights of pipe as provided here, Class A, 4-inch, being down as low as 200 pounds, and the very heaviest class only being 240 pounds. I think the experience of pipe

manufacturers has been that those figures have been very radically exceeded in average work, running from 230 as a minimum, perhaps, to 260 or 270 as a maximum, instead of from 200 to 240.

I just mention these points, Mr. President, as briefly indicating our views on the matter.

THE CHAIRMAN. It has always seemed to me that if there was any difference in the quality of the iron the best iron should be in the bell end rather than to have it in the spigot end.

MR. DEXTER BRACKETT. In explanation of some remarks made by Mr. Edwards, I wish to state, with regard to defective spigots, that this clause in the specifications is intended to provide that the spigot ends on pipes smaller than twenty inches shall not be cut off under any condition. This rule I have followed in my practice, and I think it has been followed by many other engineers, and I might say that the foundrymen do not seem to have any difficulty in making pipes of which a very small percentage are rejected for that cause. The reason for allowing a small percentage of the larger sizes to be cut and banded is that the loss of a large pipe is of more importance than of the smaller sizes.

In regard to the casting of the special castings in loam, I must say that the insertion of that clause in its present form was a mistake, as I knew that special castings, of the smaller sizes, are not made in loam, and although the specifications state that they may be made in other ways by special permission, it would hardly be desirable to require special permission for every order for small castings.

With regard to the suggestion that the hydrostatic test required is excessive for smaller sizes of pipe, I would say that if any criticism were to be made it should be made in directly the opposite direction. For the smaller sizes of pipe, the formula used provides an addition of .25 of an inch in thickness for deterioration by corrosion. For this reason, the thickness of the smaller sizes is double that needed to withstand the pressure for which the pipes are designed, while for pipes of large diameter the addition of .25 of an inch is a much smaller proportion of the total thickness, and there is more risk of getting an excessive pressure in testing the large sizes than there is in testing the small ones. I think that any of the smaller sizes of pipe will probably withstand, when new, a pressure of one thousand pounds per square inch.

MR. W. H. RICHARDS.* It is with much hesitation that I offer any

* Superintendent of Water Works, New London, Conn.

criticism of the specifications for cast-iron pipe as presented by the Committee, knowing the difficulties under which the Committee labors in an endeavor to reconcile the many divergent ideas on the subject; but as suggestions are invited, I offer the following: —

(1) That the specification contain a specific declaration that no cut pipe under twenty inches in diameter will be accepted.

(2) That the hydrostatic testing pressure be reduced as the size of pipe increases, thus giving a more nearly uniform strain on the iron. As specified, the actual strain on a 24-inch Class D pipe is double that on a 6-inch Class D pipe, which is inconsistent.

(3) That further consideration be given by the Committee to the depth of bells. Examples are not wanting in nearby cities of bells on 10-inch and 12-inch pipe less than three inches deep, and after years of use. As the saving in weight of one inch depth on the bell is nearly equivalent to all the saving between two classes of pipe, there ought to be a good reason given for adhering to an antiquated design.

Mr. Brackett. The thickness in the small pipes is not required to withstand the internal pressure, but the strain due to settlement. In fact, I think in Boston they now use fully as heavy pipes for gas as they do for water.

Mr. Robert J. Thomas. I would like to hear from Mr. Macksey, of the Boston Water Works.

Mr. H. V. Macksey. I have very little to add to the discussion at this time. Mr. Edwards seemed to think that the branding of the classification would cause some difficulty for the manufacturers. I cannot see that any great expense would be caused thereby. My experience has been that manufacturers have always kept very well within the weights specified, the pipe running too heavy rather than too light as a rule; but if a manufacturer feared that he could not keep within his limits and would have a wrong letter branded on a pipe, I see no reason why he could n't brand all the letters in series on a pipe and then take the one which fits the pipe as cast. For instance, he could have three class brands and then cut off the two which do not fit. There would be very little labor lost. So, also, in regard to putting on any special water-works brand which may be desired, and the numbering of the pipe. It seems to me very important that there should be a method of identifying pipe, because experience has shown that quite a number of pipes which have been condemned at the factories reach the works. It is a very

easy matter for the manufacturer to cut off any brand, provided the pipe is rejected at the foundry. It has been my practice to request that that be done immediately, and the manufacturers have always complied, with the exception of one who made it a practice to break up all small pipe which were refused by inspectors, never putting any into stock. So really I cannot see that these little things would make any practical difference to the manufacturers, and I think they are very important to water departments. I quite agree with the Chairman that the place to have good iron is in the socket, and I think that the specification as to the position in which the pipes should be cast is quite important.

The Chairman. I will call upon Mr. Gould, engineer of the Gas Companies.

Mr. J. A. Gould.* I do not know that I have anything of importance to add, only, as the subject of gas pipes has been mentioned, I will say that the gas pipes used in the city of Boston are as heavy as the high-service pipes which are used by the Boston Water Department. A 12-foot length of 8-inch gas pipe weighs six hundred pounds, the same as pipes used for the high-pressure service, while the gas pressure is about two ounces to the square inch.

The Chairman. Do you have any breaks?

Mr. Gould. We do.

I do not think I have any real criticism to make upon the report of this Committee, but will mention one thought that has occurred to me; that is, whether it is necessary to have so many different classes of pipe, varying for each fifty feet of head, or for each twenty-two pounds of pressure.

A pipe that is thick enough to take a good thread for the service tap is strong enough to stand the water pressure of most water works. For instance, a 6-inch pipe that is three-eighths inches in thickness can be tapped satisfactorily for water or gas services; and this is practically the thickness of a light-weight gas pipe. This pipe, if made of iron of the standard tensile strength of sixteen thousand pounds to the square inch, should not break until it is subjected to a water pressure of two thousand pounds to the square inch.

The danger to most pipes is not from the pressure in the pipes, but from the strains due to the settlement of the material in which

* Chief Engineer, Brookline and Dorchester Gas Light Companies.

the pipe is laid. For this reason it has been the custom of the local gas companies to order two classes of pipes; one which corresponds closely to the Class B of this report, or suitable for one hundred feet of water, is laid in the suburban districts, and another class, which has practically the same weight as the high-service pipe of the Boston Water Department, is laid in city streets where the pipe is liable to be undermined by other parties, especially the Sewer Department.

In this connection a list of the weights of gas mains laid in Boston and vicinity may be of interest.

Diameter, Inches.	*Suburban weights, Pounds per 12-ft. length.*	*City weights, Pounds per 12-ft. length.*
4	230	260
6	350	400
8	500	600
10	675	800
12	850	1 000
16	1 300	1 485
20	1 850	2 100
24	2 400	2 700
30	3 600	4 000
36	5 200	5 200
42	6 200	6 200

By comparison with the tables of weights in report of the Committee, I think few water-works engineers would hesitate to trust the pressure from their works in pipes of above weights, while the gas engineers with no internal pressure in their pipes demand these heavy pipes for other reasons.

Mr. Frank L. Fuller.* I think this Committee has done a good thing in recommending a scheme by which foundries can make pipe to keep in stock. We all know how troublesome it sometimes is, when we are in a hurry to get an order of pipe, to have to wait for it to be cast, because we cannot get just what we want. Now it seems to me that this will obviate that trouble to a large extent, and I think there will be less pipe laid which is unnecessarily heavy. I remember that the first pipe which was laid in the town of Marblehead was a 10-inch line, bringing water from a little pond to supply several hydrants. I do not suppose the head was more

* Civil Engineer, Boston, Mass.

than fifty feet, but that 10-inch pipe weighed eighty pounds to the foot, which, of course, was vastly heavier than there was any necessity for.

On page 92 it is specified that "No pipe shall be accepted when the thickness of metal in the body of the pipe is more than .08 of an inch less at any point than the standard thickness given in table No. 2." It seems to me that would be a little difficult to carry out, although, of course, it is a good thing. We often test pipe by rolling it to find whether it is of uneven thickness; but it would be rather difficult to caliper pipe at the center and find out just what the thickness is.

Under the head of "Special Castings," near the bottom of the same page, it reads that they "shall be made in accordance with the cuts and the dimensions given in the tables forming a part of these specifications"; and it says elsewhere, or has been stated by the Committee, that the weight of specials should be determined in advance. I do not see, unless the length of the branches is given, how the weight of the specials can be determined.

With reference to how the pipe shall be cast, it seems to me that perhaps on the whole it would be better to have it cast bell down and get a good bell. But, on the other hand, we often get a good many poor spigots, and in my experience I have had very few cracked bells. There have been a great many more cracked spigots than cracked bells. If they were cast bell end up, I should expect better spigots.

Referring to testing pipes, the specification says, "They shall also be subjected to the same proof by water pressure and hammer test after their delivery and before their final acceptance, if required by the engineer." It does not say at whose expense. I suppose that is after they are delivered to the town or city where they are to be used, but it seems to me something should be put in to make that a little more definite.

It says that castings shall be "delivered sound and perfect," and it there refers to the way in which they shall be cast. There is one trouble in connection with the receipt of pipes when they are not inspected at the foundry. They may be all right when they leave the foundry, but when they are put upon the railroad there comes in the question of a divided responsibility; and in my experience I have found that by the time the pipes were laid along the trench there were often many cracked spigots. The makers would insist that the

pipes were all right when they left the foundry, and say that the cracking took place on the railroad cars; and I presume this may be to a large extent true. In switching and shifting, the cars are often thrown violently together. As there are generally two tiers of pipe upon a car, the spigots come in contact with the pipe opposite, and very likely a good many spigots are cracked in this way. And then, again, I have seen a good many pipes that were badly cut into by the fin on the bead of the adjoining pipe. The fin would be very hard, sharp, and thin, and it would cut not only through the coating, but into the pipe itself. Of course, being on the outside, it would not do the damage that it would if it were on the inside, but at that particular point it cuts through the coating and allows corrosion to begin.

It seems to me that the dimensions of the depth of socket and the joint room agree very well with average practice, and I think that the Committee has done good work and deserves our thanks for putting this matter in such shape as it is now in; and I believe that with the changes that are likely to be made we shall have made good advance in pipe specifications.

Mr. E. H. Gowing.* I should like to say a few words about this matter of thickness of pipe, in reply to the suggestion made that it is perhaps unnecessary to have more than one size, and have that heavy enough for everything. That might be very well in places where people have lots of money; but some of us are poor, and cannot afford it. The 8-inch pipe which the gentleman said weighs six hundred pounds to a length will, at the present prices, cost ten cents a foot more than another class of 8-inch pipe which it would be quite proper to use in a great many places. That means five hundred and twenty-eight dollars a mile, or for a ten-mile system in a small country town it would mean over five thousand dollars. In many places five thousand dollars means much more than it does to the large gas companies or the water departments of large cities; so that if lighter weights can be used in these small places, I believe they should have a chance to get them. I think practice has abundantly proved that the lighter weights are practicable under many conditions, and so I want to support the Committee heartily in their plan of different classes for different situations. Pipe laid in a city street, particularly gas pipe laid near the surface, is subjected to strains which water pipe laid in a 6-foot trench in a country town

* Civil Engineer, Boston, Mass.

never meets. It seems to me that the man who orders the pipe should have sense enough to order a heavy weight pipe for a city street, and a lighter pipe for a country road where there will be no strains due to settlement, where there will be no teaming to affect it, and where it can remain in its position for years without ever being subject to outside strains of any kind. I have some other things which I may want to speak of later, for certainly this discussion will have to go over to another day, and I will say no more now.

(*January 8, 1902; discussion continued from December meeting.*)

Mr. Coffin. I believe the Committee has nothing new to offer to-day, Mr. President. Since the last meeting a few written discussions have been received, but the Committee has taken no further action, and we are waiting for further discussion before we submit our final report.

Mr. Brackett. As Mr. Coffin has stated, we have received a number of discussions, and possibly if they are read it may bring out further discussion here. I may say that we have received letters during the past month from the pipe manufacturers, stating that they have not yet been able to get together for a conference, but a meeting has been appointed to be held on the 16th of this month. After that meeting we expect to have a conference with a committee representing the pipe founders, and then may be able to report the specifications in somewhat more final form.

Mr. Leonard Metcalf.* After the excellent report of our Committee I hesitate somewhat, Mr. President, to appear to criticise it, but there are certain points in the specifications on which I had hoped there might be some discussion. Perhaps I have viewed the specifications from a little different standpoint from that of many members, that is, from the standpoint of the small purchaser, who wishes to be safeguarded in the quality of the pipe which he buys in the open market, just as is the large city which has its engineers, and which has an inspector at the foundry: and in that connection I had certain suggestions I wanted to bring forward as to changes in the specifications.

First of all, there are two or three paragraphs in the specifications as printed where the matter of tests is left to the discretion of the engineer. If I remember rightly, the hydrostatic test is the only

*Civil Engineer, Boston, Mass.

one which is definitely required of the foundry. The hammer test, in conjunction with the hydrostatic test, is left to the judgment of the engineer, as is also the making of tests of the properties of the cast iron by means of little beams, — transverse tests. Now, it has seemed to me that if it is worth the while of the large cities, which are purchasing large amounts of pipe, to have these tests made, it should be equally worth the while of the small consumer to know that he is getting pipe of the grade called for in these specifications, an equally good pipe, in short; and the only way in which he can do that is to have tests made in a similar manner.

In many cases, — perhaps in most cases, — it would be out of the question — according to his way of thinking, at any rate — for him to employ an engineer and to have a pipe inspector upon the ground; and it seems to me that the specifications should be drawn in such a way that if he calls for pipe under these specifications he will get the same kind of pipe that the larger cities, buying pipe under these specifications, would get through their engineers.

Taking up these points one after the other, briefly; — I will refer first to the paragraph under "Quality of Iron," the beginning of the second paragraph: "Specimen bars of the metal used, each being twenty-six inches long by two inches wide and one inch thick, shall be made without charge as often as the engineer may direct" (*i. e.*, left optional with the engineer). In other words, if there is no engineer, the foundry will not make such specimens and will not test them. I would therefore suggest that in that paragraph such a sentence as this might be embodied: "In default of definite instructions the contractor shall make and test at least one specimen bar from each heat or run of metal."

Taking up the hydrostatic test as the next point, making the hammer test in conjunction with the hydrostatic test, I would strike out the clause, "If required by the engineer," and make it read that the pipe shall be tested by hydrostatic pressure, — "And they shall also be subjected to a hammer test under this pressure." With the inspector on the ground, of course, that may be dispensed with, so that the engineer of the large consumer may use his own judgment; but under other circumstances the test would be made.

The third point is in regard to the method of quoting prices upon the pipe and making settlement for it, — whether we should use the long or the short ton. It seems to me it would be desirable to have that appear in the specifications as a mere matter of convention and

convenience; and to this end I would suggest in the paragraph under "Weighing," that some such clause as this might be inserted: "Bids shall be submitted and final settlement made upon the basis of a ton of two thousand pounds."

Finally, under the heading "Contractor to Furnish Men and Materials," I would change the last half of the paragraph so as to read, "And if the pipe is not inspected at the works by the engineer, the contractor shall furnish a sworn statement that all of the tests have been made and the requirements fulfilled, and if the pipe is specially cast to fill a given order the specific results of the tests shall also be submitted." This would do away with the complaint that the manufacturer might make that he could not keep track of the individual pipe that he puts into stock and of the tests which he made of the material which went into this pipe. Where the pipe is taken from stock, the consumer would merely know that all of the pipe which is in stock had passed the tests, but the large buyer, for whom the order is specially cast, would, of course, have the specific tests covering that pipe.

Referring to the hydrostatic tests which are required, it seems to me that the pressures which are stated here are small, particularly for the lighter weight pipe. Certainly, in many of the smaller water works which have been built in this country, very much lighter weights have been used than — or, let me put it in this way, — as light weights as Class A pipe of this table have been used for pressures of 100 to 125 pounds, under specifications requiring a hydrostatic test of 300 pounds per square inch. I have taken the figures which are given in these tables for the thickness of pipe, and figuring backward, making use of the factor of safety of 5, which is suggested, have figured out the pressures which the pipe should stand. Upon that basis it would be entirely safe to use very much higher hydrostatic pressures than are called for under this test. Indeed, it might well be as high as 300 pounds for pipe of all classes up to 10 or 12 inches. That is, I find, for instance, in Class A, that on the 4-inch the strength is five times 561 pounds; the 6-inch, five times 418; the 8-inch, five times 346; the 10-inch, five times 310; the 12-inch, five times 270 pounds, and so on. So it seems to me that the hydrostatic pressure might well be increased considerably beyond the limits suggested in this report.*

That brings up the question as to the number of classes of pipe

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* See Table B, page 123.

— Diagram —
SHOWING THE
Variation in Weights
— AND THE —
Overlapping of Individual Classes of Pipes
UNDER THE CLASSIFICATION SUGGESTED BY
The New England Water Works Association
Committee on Standard Specifications for Cast Iron Pipe
DECEMBER 11, 1901

LEONARD · METCALF MARCH, 1902

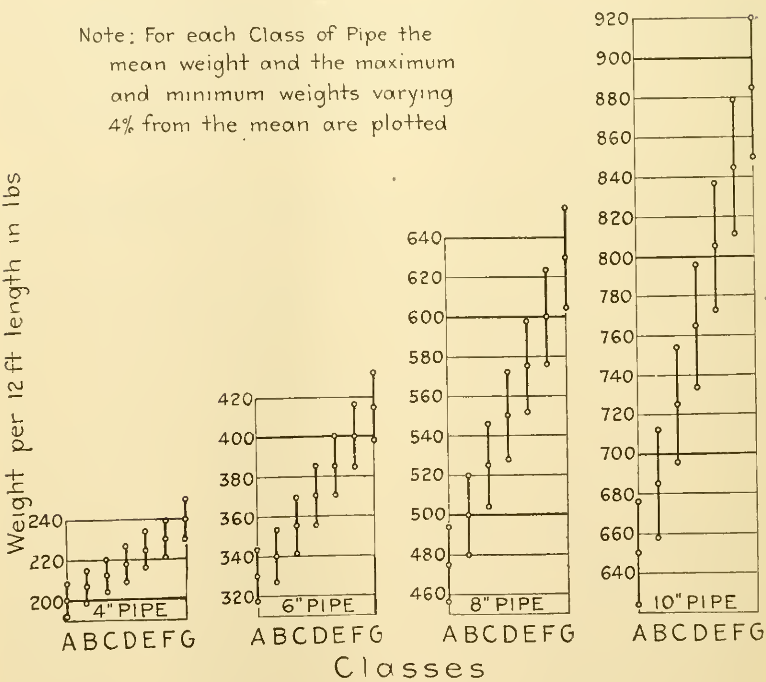
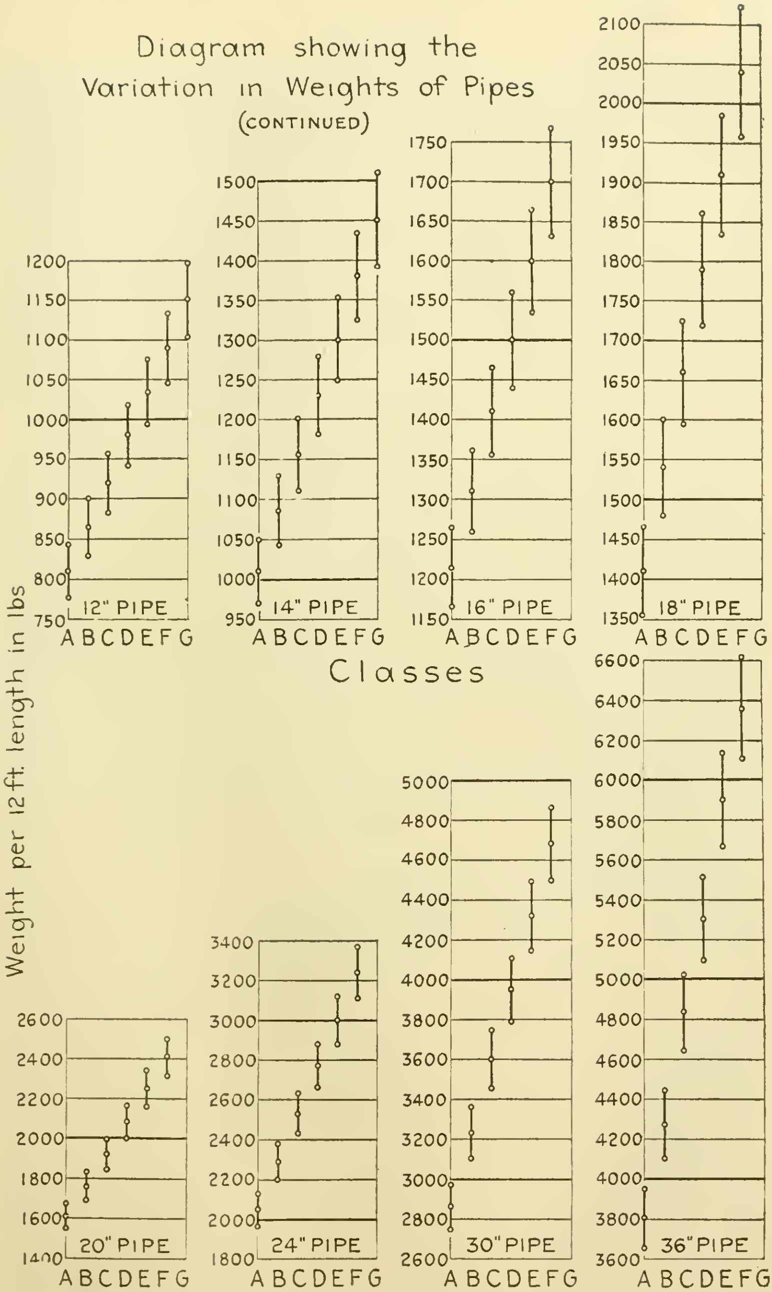


Diagram showing the Variation in Weights of Pipes

(CONTINUED)



which we should have. Under the tables which have been submitted here, and using an allowable variation on individual pipe of four per cent. each way, pipe of one class lap over into the next class; that is, the minimum weight of one class is less than the maximum weight of the class below it, and in some cases the smaller pipe even lap into the second class beyond. The accompanying diagram, pages 116, 117, illustrates this point. It seems to me that the necessities of ordinary practice would be met, probably by two classes but certainly in the smaller pipes by three classes. And I would suggest to that end that the Classes A, C, and F should be used, omitting Classes B, D, and E. In that way all overlapping would be avoided, and we would n't find the condition which might prevail under these specifications, — that is, a lighter pipe actually being used on the high service of a city than is used in the low service of the same city, as a result of this four per cent. allowable variation. If we were to adopt three classes, instead of five classes, we could then use as a hydrostatic pressure test for those three classes, — for the small pipe up to, say, 12 inches in diameter, 300 pounds on Class A and Class C, and 350 pounds on Class F, as is suggested by your Committee; on Class C, for all pipes above 12-inch, 250 pounds, and on Class F, for all pipes above 12 inches in diameter, 350 pounds, as the Committee suggest. Upon Class A we would, however, have to decrease the hydrostatic pressure test gradually; that is, from 300 pounds on the 12-inch diameter to 250 on the 14-inch and 16-inch, 220 on the 18-inch, 20-inch, and 24-inch, and 150 pounds on the sizes larger than 24 inches.

Another thought suggested itself to me in connection with the larger pipes. It is not a question with which many works have to concern themselves, and I therefore hesitate to mention it, yet it occurred to me that it would be well for the Association to recommend that for pipes over fourteen inches in diameter new works at least should adopt but one or perhaps two diameters for different weight pipes of the same nominal diameter, and avoid the necessity which exists under the proposed specifications of having three different sizes of pipe of the same nominal diameter.

The formula for thickness of pipe which is suggested by the Committee seems to me to be a thoroughly rational one, and gets away from the inconsistencies of some of the older formulæ which have been used, in which a constant was added in order to prevent breakage or to cover the danger of breakage in the shipment of

pipe. In this connection it may be of interest to mention a paper that Mr. N. Henry Crafts published, in the form of a report to the town of Watertown, in 1876, which, apparently, has had considerable influence in determining the weights of the smaller sizes of pipe that have been used in many of the small works that I speak of. I have with me a list of the weights which have been used by Mr. William Wheeler in his practice in some fifteen or twenty works, which are very much like the lighter weights that Mr. Coffin spoke of at one of the meetings during 1900,* and which I should be very glad to summarize for publication in the JOURNAL if you think it would be of interest.

This is all I have to say, Mr. President.

MR. COFFIN. I did not expect to take any part in this discussion to-day, but Mr. Metcalf has raised several interesting points, about some of which I quite agree with him, and I would like to say something about them just at this time. The Committee have had a good many very valuable suggestions presented to them, and will consider all of them; but I would ask the members to remember that there are several points of view in this matter, and the Committee, whatever the personal preferences or ideas of its individual members may be, has to consider them all. What would suit one person would not suit another, and it has been the endeavor of the Committee right along to get a specification which might, on the whole, be acceptable to everybody. In saying this, speaking just after Mr. Metcalf has spoken, I do not mean to be understood as being antagonistic to any of the points he has suggested in the way of changes. The Committee will consider them, but still it may be that, while some of the suggestions are very valuable, — looking at the subject from one point of view, — the Committee may not be able to recommend the adoption of any of them.

He has spoken of the weights in the different classes, and I want to refer to that now, while we are all here, hoping that there may be further discussion upon it. The matter has been very thoroughly considered in Committee, and while some of us would prefer more simplicity in the classes, still it seems to me that if we are going to prepare a list of weights which would be acceptable as a general list for specifications, we must have more than three classes; not that any one man may use as many classes as another, but that any

* See "A Few Notes on Cast-Iron Pipe," Journal New England Water Works Association, September, 1900, Vol. XV, p. 38.

engineer in buying pipe may be able out of those classes to select a list which will suit his practice. For instance, I could pick out of that list three classes which would cover everything I should care to use. Another engineer might also pick out three classes, but would, perhaps, want different classes from mine. He might want heavier pipes for certain cases than I would, or he might want lighter pipe. That was the idea of having all these classes.

It is very easy to see that it would be better, if possible, to have fewer classes, more especially, I think, on account of lettering the pipe. If the founder has to letter the pipe, he does n't know when he casts his first pipe in any lot just where he is going to strike; it is a matter of experiment, as I understand it. He may cast pipe intended for Class B and they may run over Class B into Class C, or possibly run under into Class A; and if the letter is cast on it, of course that fixes the class and he must lose the margin, or it must be arranged in some other way. That, I should imagine, would be one of the criticisms that the founders will make, and it is, as far as I can see, the worst objection to our classification. I therefore wanted to explain why the weights were classified in this way.

I was very glad to hear Mr. Metcalf speak of his practice in using different weights of pipes. I suppose you have noticed in reading the report that the Committee had tried not to commit the Association to the endorsement of any particular weight of pipe for special work or special conditions. The Committee has explained how the classes have been computed, but in the specifications themselves there is nothing to commit the Association to any weight for any pressure in any class. I think it is very desirable to have some discussion on that point, and I, for one, would be very glad if Mr. Metcalf would tabulate his weights and have them go into this discussion.

Mr. Brackett. I would like to ask Mr. Metcalf whether he would build a reservoir or a filter gallery or a system of sewerage without inspection, and take the sworn statement of the contractor that the work had been carried out in accordance with the specifications. That, I understand, is what he proposes to do in the case of cast-iron pipe. I do not think you can be sure of getting good work unless you employ an inspector to see that it is done in accordance with the specifications. Some of the points which Mr. Metcalf has mentioned were intended to be covered by the specifications, and I think he will find that they are. I may say that in general I agree with his suggestions.

Mr. Metcalf (by letter, March 27, 1902). In further comment upon the subject of the weight of cast-iron pipe, I send herewith a table of weights of cast-iron pipe according to different authorities (Table A, page 122).

Without attempting to state specifically all of the weights of pipe used by Mr. William Wheeler upon different water works constructed by him, I have tabulated under the head of "General" and "Heavy" the two classes of weights ordinarily used by him, — the first for service in small communities; the second in cities where considerations of heavier street traffic, greater liability to future disturbance by excavations in the street, and heavier pressures for high service, govern.

The class "General" has been used even under such high pressures as those prevailing at Winchester, Ky., a city of about six thousand inhabitants, in which the pressures have the following range: —

On the 12-inch pipe, from 30 to 60 pounds per square inch.
On the 10-inch and 4-inch pipe, from 45 to 125 pounds per square inch.
On the 8-inch and 6-inch pipe, from 50 to 75 pounds per square inch.

The class "Heavy" was used, for instance, at Knoxville and North Knoxville, Tenn. (and other cities), where a population of about forty-five thousand or fifty thousand is supplied, and where the pressures range from thirty to one hundred and twenty-five pounds.

The weights used by Mr. Freeman C. Coffin are quoted from the Journal of New England Water Works Association for September, 1900, with the exception of those contained in the last column, marked "Lightest," which were kindly given to the writer by Mr. Coffin.

The weights suggested by Mr. N. Henry Crafts were taken from his report to the town of Watertown, Mass., dated July, 1876.

It seems hardly necessary to reply to the question of Mr. Brackett, as to whether the writer "would build a reservoir, or a filter gallery, or a system of sewerage, without inspection, and take the sworn statement of the contractor that the work had been carried out in accordance with the specifications." He would certainly not to do so, and as Mr. Brackett doubtless knows, he is a thorough believer in the careful inspection of all materials of construction, as well as the actual execution of the work.

Yet the fact should not be overlooked, as previously stated by the

TABLE A. — WEIGHTS OF CAST-IRON PIPE ACCORDING TO DIFFERENT AUTHORITIES.

COMPILED BY LEONARD METCALF, MARCH, 1902.

Diam of Pipe.	William Wheeler.				Freeman C. Coffin.*								N. Henry Crafts.				N. E. W. W. A. Committee, 1902.					
	General.		Heavy.		Light.		Standard.		Heavy.		Lightest.		Light - 65 lbs. Pressure.		Heavy-150 lbs. Pressure.		Class A.		Class C.		Class F.	
Inches.	Per Ft.	Per 12' Length.	Per Ft.	Per 12' Length.	Per Ft.	Per 12' Length.	Per Ft.	Per 12' Length.	Per Ft.	Per 12' Length.	Per Ft.	Per 12' Length.	Per Ft.	Per 12' Length.	Per Ft.	Per 12' Length.	Per Ft.	Per 12' Length.	Per Ft.	Per 12' Length.	Per Ft.	Per 12' Length.
3	14	168	14	168	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4	17	204	18	216	17	204	19	228	22	264	16.4	197	18	216	18	216	16.7	200	17.7	212	19.2	230
6	28	336	29	348	27	324	30	360	35	420	26.3	315	28	336	28	336	27.6	330	29.6	355	33.3	400
8	40	480	42	504	40	480	45	540	50	600	36.7	440	39	468	44	528	39.6	475	43.8	525	50.0	600
10	53	636	57	684	54	684	60	720	70	840	50.0	600	52	624	65	780	54.3	650	60.4	725	70.4	845
12	67	804	74	888	68	816	80	960	90	1 080	64.1	768	65	780	87	1 044	67.5	810	76.7	920	90.9	1 090
14	..	1 116	93	1 116	85	1 020	100	1 200	115	1 380	79.4	952	80	960	113	1 356	84.3	1 010	96.5	1 155	115.0	1 380
16	..	1 368	114	1 368	105	1 260	125	1 500	145	1 740	101.2	1 215	96	1 152	143	1 716	101.2	1 215	117.5	1 410	141.6	1 700
18	..	..	137	1 644	120	1 440	150	1 800	175	2 100	114.2	1 370	..	..	..	..	117.5	1 410	138.3	1 660	170.0	2 040
20	..	.	162	1 944	140	1 680	175	2 100	205	2 460	133.6	1 603	134	1 608	213	2 556	134.2	1 610	160.0	1 920	200.8	2 410
24	..	..	..	..	185	2 220	225	2 700	270	3 240	..	..	175	2 100	298	3 576	170.8	2 050	210.8	2 530	270.0	3 240

* See JOURNAL New England Water Works Association, September, 1900. "Light," safe for 100 feet head; "Standard," safe for 350 feet head; "Heavy," for city use and higher heads than 350 feet.

writer, that with much of the pipe that is laid there is no inspection of the pipe prior to its superficial examination on the ground where it is to be used.

Hence the writer is of the opinion that the Association should do all in its power to maintain and improve the standard of the product turned out at the pipe foundries in the interest of the small consumer as well as of the large.

The following tables, bearing upon the hydrostatic testing of cast-iron pipe, are appended in amplification of the writer's remarks upon this subject.

TABLE B.

COMPUTED* BY LEONARD METCALF, FEBRUARY, 1902.

Diameter, Inches.	Class A.		Class C.		Class F.	
	Thickness, Inches.	Allowable Static Pressure, Lbs. per Sq. Inch.	Thickness, Inches.	Allowable Static Pressure, Lbs. per Sq. Inch.	Thickness, Inches.	Allowable Static Pressure, Lbs. per Sq. Inch.
4	0.34	561	0.36	594	0.40	660
6	0.38	418	0.42	462	0.48	528
8	0.42	346	0.48	396	0.56	462
10	0.47	310	0.53	350	0.63	416
12	0.49	270	0.57	313	0.69	379
14	0.53	250	0.61	288	0.75	354
16	0.55	226	0.65	268	0.80	330
18	0.57	209	0.69	253	0.86	316
20	0.60	198	0.72	238	0.92	304
24	0.64	176	0.80	220	1.03	284
36	0.79	145	1.02	187	1.37	251
48	0.95	131	1.25	172	1.70	234
60	1.10	121	1.50	165	2.10	231

* By slide rule.

HYDROSTATIC TESTS SUGGESTED BY L. METCALF.

Diameter of Pipe.	Pressure (Pounds per Square Inch).		
	Class A.	Class C.	Class F.
3 in. to 12 in., inclusive	300	300	350
14 in. and 16 in.	250	250	350
18 in., 20 in., and 24 in.	200	250	350
30 in. and over	150	250	350

Mr. James H. Harlow* (by letter). I am in receipt of an advance copy of the report of the Committee on Standard Specifications for Cast-Iron Water Pipe.

In looking over the report somewhat hastily, I have been struck with the weights recommended by the Committee in Table No. 2. In this connection I would follow the Committee where the Committee says, "Believing that to the engineer or superintendent should be left the final decision as to the thickness of weight of pipe suitable for the particular place in which it is to be used."

I note the Committee recommends an allowance for water hammer of one hundred and twenty pounds in the small and about seventy pounds in the larger sizes. From my experience on the pipe lines of the Pennsylvania Water Company, it seems to me this water-hammer allowance is far in excess of the necessities of the case. The Pennsylvania Water Company's pipe lines are subject to a static pressure of about one hundred and fifty pounds per square inch. This, during the day-time period of greatest demand, is reduced to about one hundred and thirty-five pounds. As will be seen by the daily record enclosed,† we have no hammer in our lines, and in the experience of twelve years since this work has been constructed, I do not recollect of a water hammer that would exceed ten pounds, as shown by the recording gauge.

Again, it seems to me that the .25 of an inch to be added to the calculated thickness of pipe is hardly necessary.

With the exception of 4-inch pipe, the weights given under Table No. 2, Class C, are about the weights used by us, in the place of Class G, shown in the table.

The Pennsylvania Water Company has a mileage exceeding one hundred miles of pipe, varying in size from six inches to forty-two inches.

If pipes of Class G had been used, the interest on the excess cost would have been between four thousand and five thousand dollars per year, while the cost of making repairs to breaks in pipes, other than those caused by sinking of sewers, etc., has been less than one per cent. of this sum.

I believe, from our experience, that the weights of the pipes as given by the Committee can be very materially reduced.

We find that $t = \frac{hd}{13\ 500}$ to be safe, in which t = thickness of pipe in inches, h = head in feet, and d = diameter in inches.

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* Civil Engineer, Pittsburg, Pa. † Not reproduced. — Editor.

I am pleased to see that the Committee recommends that the outside dimensions of the pipe are to be standardized, making the variations for the several thicknesses on the inside of the pipe, as this will enable special castings to be standardized also.

Mr. Brackett. If no one else desires to say anything at this time you may be interested to hear some of the written discussions which we have received. To show the interest which is taken in this question, not only here but abroad, I will read the following from the British Association of Water-Works Engineers: —

London, December 17, 1901.

Dexter Brackett, Esq.,
Boston, Mass., U. S. A.

Dear Sir, — I am much obliged for your letter enclosing a copy of the report of your Committee on Standard Specifications for Cast-Iron Pipe, which was submitted to the New England Water Works Association on the 11th inst. I much regret that this was not forthcoming for the consideration of our Association at their meeting on the 7th inst., more particularly as in the course of the discussion on that occasion the question of standardizing cast-iron pipe dimensions, etc., was strongly urged by many of the speakers, and was, in fact, referred to our Council for further consideration. . . . I should like to ask you, as one of the Committee, whether there would be any objection to our publishing this report, and also whether you could let me have, at an early date, a record of the discussion which took place at your meeting.

I am sure my Council will highly appreciate the opportunity of enabling the water-works engineers in this country to coöperate with their brother engineers in America both in connection with this subject and any other of the many problems which from time to time call for solution at their hands.

Thanking you on their behalf for your interest in our proceedings, which I am sure will be heartily reciprocated, I remain,

Yours faithfully,

Percy Griffith, *Secretary*,
The British Association of Water-Works Engineers.

Mr. Brackett. I have a discussion from George E. Manning, of New London. I am not acquainted with the gentleman, but I judge from what he has written that he is familiar with the manufacture of pipe.

Mr. George E. Manning * (by letter). The feature of the design which provides that the outside diameter for each size shall be uni-

* Civil Engineer, New London, Conn.

form and all changes of thickness made by changing the inside diameter is to be commended, not only from the pipe-layer's point of view, but because the manufacturer can consider it a concession to his interests. Changes of the inside diameter can be easily made in a few minutes; but to change the outside diameter requires the casting of an iron pattern and the turning of it down in a lathe to the proper size, and if three pipes are cast in one flask, as is the practice for small sizes in some foundries, three patterns must be made.

A foundry cannot give a low price and go to this expense for a small order.

The extra patterns, which the other method requires the maker to provide, deteriorate from rust when not in use almost as fast as by use.

There are three methods of making the molds for cast-iron water pipe.

1. *Dry-sand molds*, used for straight pipe.

2. *Loam molds*, used for large special castings. In this case a rough form is built out of bricks. This is covered over and brought to the exact shape desired with a clayey material, which, when baked, is a low grade of brick itself. A loam mold is expensive to make, but is quite sure to give a good sound casting.

3. *Green-sand molds* are used for all small special castings. This is the process in use in all iron foundries. The Association should not adopt a standard specification that required the maker to obtain, in writing, permission to use green-sand molds for small specials.

There has been a great deal said as to which end of the straight pipe should be cast down. An examination of the scrap heap at a pipe foundry will show that this is one of the most important items of the specifications. The carbon, silicon, etc., which are constituents of all cast iron, are of less specific gravity than the iron itself. When the cast iron is in a fluid state these lighter parts are constantly rising toward the surface. When the spigot is cast up, the runners cover the upper surface of the end of the pipe so well that the lighter matter readily rises into the casting head, leaving the pipe itself in good condition.

With the hub end cast up, the runners cover but a small part of the end of the hub, and the bottom of the socket also provides a lodging-place for the cinder. The hub of a pipe cast with that end up will, in almost every case, show, when broken, holes and

collections of cinder. When subjected to the proof of three hundred pounds to the square inch hydrostatic pressure, leaks will frequently show at once, but in many cases the water will begin to come through only after the pipe has been under the pressure two or three minutes. Upon examination it is often found that the passage for the water is several inches long from the point of entrance to the outlet.

All makers cast large pipe with hub end down, and some cast all sizes that way. A pipe maker who has the facilities for doing the work both ways will, if he has had experience with inspectors, usually prefer to make the pipe hub down for rigid inspection ; for he knows there will then be fewer rejections.

The hydrostatic test, or proof of the pipe, is a most important item of the specifications. Where a good inspector is not standing by, however, it is often little more than a farce. More pipes are cast at some foundries than can be put through the proving press, if sufficient time is given to each one. The standard specification of this Association should provide that the pressure be held for at least one minute.

Providence and other cities where Mr. Shedd has been the engineer employed are using pipes with a depth of bell much less than that given in the table. If a depth of two and a half inches gives good joints, why buy iron to make a depth of three inches? No more lead is used for the deeper joint, I am told, but the difference is in the amount of yarning used. This, I am told by men who have calked both kinds of joints, tells against the deeper joint. It is more difficult to compact the lead against the larger quantity of yarn.

A part of the depth of the socket is to provide for irregularities in grade, and for all slight changes in direction. If the end of the spigot is drawn away from the bottom of the bell on one side only one-eighth inch for each two inches of the diameter, a change of direction of three and one-half degrees is made. Perhaps that is nearer to a straight line than the work can be done in many of the hilly streets of New England cities ; but in some places, all street work is now laid out with so much care that a line of pipe can be laid within that limit.

The curve of large radius, shown at the bottom of the bell in the drawing, is correct for the design of special castings cast in green-sand molds ; but the method of making the different parts of a dry-

sand mold for straight pipe cast bell end down is such that a shape like that shown must be made with the trowel, — extra work, for which the socket maker is not paid and so seldom does. The bead at the spigot end can be made in a shape to correspond, with advantage to both maker and user. The change in the bead suggested is a triangular instead of a nearly half-round shape, when shown in section, — the largest diameter through the bead being nearly at the end of the pipe, and the end nearly square across. When joints are made with pipes having the sharp corners suggested, instead of a round-cornered design, there is more room for the yarn, and a smaller quantity can also be used with more confidence that it will not let the lead run through, so that less depth of socket is required.*

Under the present high-pressure methods, cast-iron pipes are generally shaken out of the molds too hot — often red. It would be hard to say just how much difference this makes; but there can be no doubt that cooling quickly causes the crystals of cast iron to be inferior in quality, and sometimes a condition of strain within the casting itself. The writer has seen a 30-inch pipe, one and one-eighth inches thick, crack open in two places, from one half to two thirds its length, at the bell end, when under less than three hundred pounds pressure, the sides of the cracks at the end of the pipe remaining rigidly about one and one-half inches apart. It was a pipe shaken out while still red; and there appeared to be no other reason for its behavior than the unequal contraction in cooling. This pipe had been rejected because the same condition had been indicated by its being badly out of round.

Some foundries practice the making of two pipes in the same flask in one day; others one per day, while others have provided two full outfits of flasks and core-bars, and make casts in them on alternate days. The pipes remain in the flasks over night, and are perfectly cold when shaken out. This process must give the best quality of pipe, other conditions being the same. As all the flasks and core-bars are of the same temperature when the new molds are made, the pipes are more uniform in weight. Many of the defects of casting are thus avoided.

It is provided that specimen bars shall be cast without charge. It would not be too much to specify that the use of a standard testing

* See "A Discussion of Pipe Joints," submitted by Mr. Manning for the February meeting, and printed on page 130. — EDITOR.

machine for breaking the bars should be furnished by the contractor. Otherwise it might be held by him that the clause that provides that he shall furnish the tools for the inspection of pipes did not cover the machine for breaking specimen bars. The breaking of these bars is not of vital importance, but it is thought that by means of it a better knowledge of cast iron will be gained by all concerned.

It is desirable also that the Association should, if possible, do something to promote the chemical examination of the mixtures for cast-iron pipe. A case in mind is what occurred at a foundry where nothing but 30-inch pipe were being cast. The mixture put into the cupola was brought from four different furnaces. For a thickness of seven-eighths inch and one inch the castings were good and sound, but for a thickness of one and one-eighth inches, less than ten per cent. could be accepted for several days at the start. The castings were porous and leaked badly through two or three feet of the pigots (upper) end when proved. This could not be helped by the inspector or buyer, but it was not pleasant for them to have it occur.

It is the writer's observation that good large and thick pipe cannot be made with the iron that will make good small pipe.

The metallurgical chemist's knowledge of steel is such that contracts are made which specify what per cent. of carbon and other ingredients it shall contain, according to the purpose for which it is to be used.

The large scale processes of making steel, such as the Bessemer open-hearth, or basic, have always been, and the reduction of the ores in the furnaces is now, as a rule, under the direction of metallurgists, and is conducted in a scientific manner.

The iron-founder's art is older than the science of chemistry. Its processes are still based largely on the traditions of the art. The services of a chemist are seldom employed. The olden-times iron-founder, who could tell all about cast iron from the appearance of the fracture of the pig, was successful as long as the pigs were all from the same ores and furnaces, but was at a loss when it came to using unknown pig iron.

It is to be hoped that the time will come, and probably the time is coming, when there will be a chemist in charge at the pipe foundry.

However valuable he might be to an ordinary foundry business, he would be particularly useful at a pipe foundry where the quantity

of iron used is large, a great many castings of the same size and thickness are made, and nearly all of the work is done by men who are to be classed as common laborers when compared with the molders in green sand. Such conditions are favorable for a scientific management. A metallurgist, trained in pipe making, would know what is needed to make a certain line of castings called for by a contract. He would select the mixture and give it the heat treatment needed. Instead of running the whole foundry force for several days on experiments, turning out pipes which are sent to the scrap-pile or accepted reluctantly by the inspector, the castings would be from the beginning as sound as the best made under the usual practice of the present.

The largest consumers can now make contracts for pipe under such specifications for the design, mode of casting, inspection, etc., as they wish.

By the use of standard specifications, adopted by this Association, the smaller consumers will be able to obtain, even for their yearly extensions, first, pipe that will always fit together; second, a saving in material and cost, through a better and a uniform design; third, an improved quality, by insisting upon the important clause that the pipe shall be cast bell end down, and not giving permission in writing for bell-end-up casting, except it may be for 4-inch pipe.

To obtain pipes of even thickness, free from defects and properly proved by hydrostatic pressure, it will always be necessary to have the services of a good inspector.

A DISCUSSION OF THE DESIGN OF LEAD JOINTS FOR CAST-IRON WATER PIPE.

[*Submitted for the February meeting of the Association, by George E. Manning.*]

Years ago, when the hub and spigot form of cast-iron pipes with lead joints was adopted, it was the practice to make the depth of socket much more than it is made now.

Twenty-five to thirty years ago, many miles of pipes were laid which had a depth of socket as small as two inches for the six-inch size. That was a bold departure from the general practice, but it does not appear that these joints have given any more trouble in service than the deeper ones have. But it was found desirable to increase the depth slightly, chiefly because hilly streets have made it necessary to have small deflections in a line of pipe.

All engineers came to have more confidence in the lesser depth, and a general tendency in that direction is to be noticed in all designs of late years, probably not so much in the larger as in the smaller sizes. But, as the greater part of the large sizes are under less pressure (that is, in gravity systems, perhaps not in pumping systems), they are less subject to water hammer, and, as a rule, can be laid in a more direct alignment, — curved pipes being used for changes in direction, — it would appear that a small depth of joint is as safe for the larger as for the smaller sizes.

Another consideration is, that for 24-inch and larger sizes, into which a man may crawl, a device can be placed on the inside of the joint that will keep the lead from running through, and thus do away with the yarning and the space that it takes up in the smaller sizes. This joint can be set up on the inside as well as on the outside, and thus affords better security.

As there are many members of the Association who have used, prefer to use, and will probably continue to use, a design for pipe having a depth of socket less than that suggested by the Committee on Standard Specifications for Cast-iron Pipe, a design and table of dimensions which embody this idea are submitted for consideration. It is based on the design of Mr. J. Herbert Shedd, which is in use at Providence, Newton, and many other places.

The dimensions shown will give at least two inches for depth of joints (including bead, yarn, and lead, as such), with a deflection of not more than three and one-half degrees in the alignment.

The tangent of $3\frac{1}{2}°$ being .06145 or $\frac{1}{16}$, one-eighth inch for each two inches of difference in the diameters is taken for the difference in depths of sockets.

Beginning with a depth of $2\frac{1}{8}$ inches for a 2-inch pipe, a 4-inch pipe will have a socket $2\frac{1}{4}$ inches deep, a 6-inch pipe, one $2\frac{3}{8}$ inches deep, etc. All changes in the corresponding outside dimensions of the hub for changes in diameter have the same relation to the depth of socket.

By having the inside of the pipe flare out a little larger at the joints, the waterway of the pipe line is not reduced when the pipes are not exactly centered from any cause. This flare can be easily made at the hub end, and seems to be worth having. A flare at the hub end only gives all the benefit in case the pipe is laid with the hub end toward the flow of water, and much of it in any case. As the flare at the spigot end is more trouble to make, and would

lead to more breakage in the thinner classes, it might not be well to insist upon it in all cases.

The function of the bead at the spigot is to keep the yarn from being driven through the joint when it is being calked. A shape like that shown tends to place the yarn exactly where it is needed and to resist its going any beyond. A half-round shape of bead will tend to let the yarn slide around it into the pipe. The mold for a pipe has to be parted at the largest diameter of the bead. When the part of the mold that forms the end of the pipe is flat, or nearly so, it can be made in a more economical manner by the foundrymen than the half-round shape can be.

Attention has already been called by the writer, in a previous discussion, to the nearly square inside corner of the socket. The slight slant at the end is the shape usually given to it by the socket coremaker, as it is thought that it can thus better resist the blow from the molten iron, falling from a height of twelve feet upon it.

If any lot of cast-iron pipe is examined, it will be found that the outside of the hub joins the shaft of the pipe with a slight offset and not with a tangent curve. The pattern is parted at that point, and if the hub pattern was given the thin knife edge when it was made, it would soon be broken so as to produce the offset in the casting. It will also be found that the straight parts of the sides of hubs are at an angle and not parallel with the shaft of the pipe. This is in order that the pattern may be drawn easily without breaking the mold. It may be of interest to state that the upper end of a pipe is a little larger in diameter than the lower end, for the same reason.

There has been a great diversity of ideas shown in the design of the lead groove. Many miles have been laid with pipe that had perfectly straight joints, *i. e.*, with no lead groove at all. A groove half-round in section has been used, which is probably, when set up, of no more use than no groove, and a waste of lead. A great many pipes have been laid that have a groove which is the reverse of the Boston design, — that is, the lead has to be set up against the shorter slant. Such a joint would seem to give the calker a harder task to set up the lead in its place than it gives the water to push it out of place.

The design shown has a groove with a slant on each side of the same length, viz., seven-eighths of an inch.

The length, over all, of a pipe is always made the same as the length of the flask in which it is cast, so that of two designs cast

at the same foundry, the one which has a hub that is, say, one inch shorter than the other, will have a laying length one inch greater.

Probably most men have not become trained to think in decimals of an inch, but mentally reduce such given dimensions to eighths and sixteenths. It is also doubtful if a pattern maker's shrink rule, divided into inches, decimally, is often found at a pipe foundry. There, too, such dimensions are changed, for use, into the common fractions. If any change is to be made in the direction of a decimal system, would it not be well to consider the metric system, which is coming into use in the shops, and will be in general use by machinists, probably, sometime?

Five centimeters are nearly equal to two inches. A pipe twenty centimeters in diameter would be only one-eighth inch smaller than an 8-inch pipe. By providing for a thicker class, — which would be seldom or never used, — the outside diameter being the same for all classes, as specified, the objection of a reduced capacity would be avoided in all ordinary cases. Fifty centimeters would be five-sixteenths of an inch less than twenty inches.

It would thus appear that a change could be made to the metric system with almost no inconvenience in any way. The new standard pipe would joint with the old as well as pipes from different foundries will with each other now. The difference between sizes, being five centimeters instead of two inches, would be as easy to carry in the mind.

In the table of dimensions which follows, outside diameters are not given, as they depend upon the thickness of the heaviest class that is decided upon finally. The inside diameter of the socket also depends upon the thickness.

$$\text{Depth of socket, } D = 2 + \frac{\text{Nominal diameter}}{2 \times 8}.$$

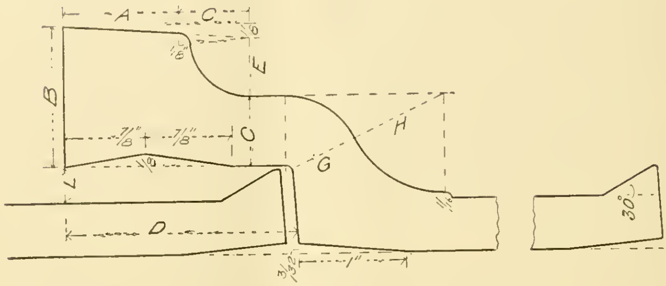
$$A = \tfrac{1}{2} D.$$

Thickness of end of hub $B = D - 1$ inch up to the 18-inch size, for which it is $2\frac{1}{8}$ inches, which is considered to be about as thick as there is any advantage in making it. But an increase of $\frac{1}{8}$ inch for each six inches on the diameter is suggested for the larger sizes.

$C = \frac{1}{2}$ B.
Radius $E = \frac{1}{2} B - \frac{1}{8}$ in.
,, $G = \frac{1}{2} B + \frac{1}{16}$ in.
,, $H = \frac{1}{2} B + L - \frac{1}{16}$ in.
L = thickness of lead joint.

The recess of the lead groove should be from $\frac{1}{8}$ inch in depth for the smaller to $\frac{1}{4}$ inch for the larger sizes.

TABLE OF DIMENSIONS FOR HUBS, IN INCHES.



Nominal Diameter	4	6	8	10	12	14	16	18	20	24	30	36	42	48
Depth of Socket	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	3	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{7}{8}$	$4\frac{1}{4}$	$4\frac{5}{8}$	5
B	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{8}$	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$
A	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{9}{16}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{15}{16}$	$2\frac{1}{8}$	$2\frac{5}{16}$	$2\frac{1}{2}$
C	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{16}$	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{3}{8}$
Radius, E	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	$\frac{15}{16}$	1	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{1}{4}$
,, G	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$		$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{3}{8}$	$1\frac{7}{16}$
,, H	$\frac{15}{16}$	1	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{3}{16}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{11}{16}$	$1\frac{3}{4}$	$1\frac{13}{16}$
Thickness of Lead, L	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Outside Diam. of Pipe														
Inside Diam. of Socket														
Class A { Thickness														
Class A { Weight														
Class B { Thickness														
Class B { Weight														
Class C { Thickness														
Class C { Weight														

Hubs for special castings to have the same dimensions, except for depth of socket, which shall be one inch more, in all sizes.

MR. HORACE G. HOLDEN. I would like to ask Mr. Brackett what was the cause of the break of the large pipe on Causeway Street, in Boston, near the Union Station, some time ago; whether it was due to a defect in the casting originally, or whether the defect was caused in moving the pipe from the foundry to the cars, or in transportation on the railroad, or in moving it from the cars to the street, or in the laying of it.

Mr. Brackett. That was a case where the pipe had been laid for many years in a soil which is more or less marsh mud, and the iron had deteriorated very much and turned to plumbago. I have had many cases in my experience where it has been very difficult to determine the cause of the break. Pipes that have been in use for a great many years without showing any visible indication of weakness have burst. There were about half a dozen breaks in the city of Boston last year on a line of 48-inch pipe which was only under about fifty or sixty feet of head, and the pipes were an inch and a quarter thick. These pipes should have withstood two hundred or three hundred pounds pressure. They had been in use since 1869, but not under quite as much pressure. A number of theories have been advanced as to the cause of the breaks, among others that slight cracks had been caused at some time by water hammer which were developed by the additional pressure.

Mr. R. C. P. Coggeshall.* Brother Holden may be interested in a case we had in New Bedford last April. It was on a 30-inch pipe, which had been laid in connection with our new works and was about two and one-half miles from the city. It had been thoroughly inspected. The pipe was fully an inch thick, and there was no way of accounting for the break, that I could see. There was a piece about five feet long and about two and one-half or three feet wide on the lower quarter blown straight out, just the same as you would take a cover off a stove, and there was n't a sign of a crack on the remaining part of the pipe. I have n't the slightest idea what the cause was.

Mr. Charles K. Walker.† I can tell you a story which I think will beat that. Last summer one of our gates, probably as good a gate as there is made, cracked from top to bottom under about one hundred pounds pressure. We had shut it off, and were repairing on the line below when the report came that there was a leak, and we went up and found the gate split from top to bottom right through the flange — an inch and a quarter flange. I have asked a good many experts what they thought about it, and they have all told me it was one of those cases which they did n't know about. I made up my mind I did n't know, and I can't find anybody so far who does. Now, if there is any gentlemen here who can tell me, I will treat him. [*Laughter.*]

* Superintendent of Water Works, New Bedford, Mass.
† Superintendent of Water Works, Manchester, N. H.

A Member. Which way did it crack, up and down or horizontally?

Mr. Walker. Up and down. The gate had been shut for two hours, and all at once there was this big leak. We happened to be working near by, so we could shut it off, and there was n't any harm done.

Mr. Holden. How large a gate was it?

Mr. Walker. Twenty-inch. There was no wedging about it, and the iron was an inch and a quarter thick. There is another thing I want to say, about inspectors. We had about twenty-five leaks on a half a mile of 20-inch pipe, and the inspector who inspected it when it was laid is right here under my eye, and he is a good, bright man. [*Laughter.*] When we went to drive in the lead in a 4-inch bell, it went 'way in. We had to hustle round to shut it off when we struck it, because it was pretty full of gasket and there was mighty little lead. Of course the contractor was n't to blame, nor the inspector, — but there it was. If there had n't been but a little gasket in there we should n't have had any trouble. I am for a good, deep bell and plenty of lead. I don't care anything about the theoretical part of it, but any man who has had experience will say he had rather have more lead and less gasket. I want a 4-inch bell on a 20-inch pipe. I have seen enough trouble with short bells. A man who has been a superintendent for a number of years knows what trouble is when he gets it, but when you tell these experts about these things and ask them what is the cause, they say they don't really know. [*Laughter.*]

Mr. F. F. Forbes.* I would like to ask Mr. Walker one question about the pipe line below the gate. How many feet fall was there, and was it abrupt?

Mr. Walker. I should think there was about thirty feet of fall.

Mr. Forbes. I once had a similar experience to Mr. Walker's. I shut off the main where there was quite a sharp fall in the pipe, and the gate at the upper end of the main broke, something like in Mr. Walker's case. At first I could n't understand the reason for it, but I finally figured it out in this way: There was more than thirty-two feet of fall from the gate to where the blow-off in the main was, and when we opened the blow-off the whole column of water left the gate and very nearly a perfect vacuum was formed. Then for some reason or other that column of water broke, and this body of water went back like a cannon ball and struck the gate and

* Superintendent of Water Works, Brookline, Mass.

shattered it to pieces. This happened where there was n't more than fifteen feet head back of a gate made by the Boston Machine Company in 1874, a very heavy gate, one of the heaviest patterns. The gate was shut down carefully by hand, and there was no pressure whatever on the gate in turning it. The gate was broken to pieces, and the only explanation I could find was what I have stated.

MR. WALKER. I am very much obliged to the gentleman for telling me what the trouble was. He is the first one who could do it, and my offer to treat holds good. [*Laughter.*]

MR. H. A. FISKE. I should like to ask one question, which has been suggested by this water-hammer incident, in connection with some trouble we have had recently in a New England town from excessive water hammer caused by interior fire protection. I never knew of anything like it before, although we have fire protection devices of the same nature in other places. The water-works people in this town have had trouble from breaks caused by water hammer, and they claim that the device, which is a sprinkler system with air in the pipes, should not be allowed to be used, because it causes water hammer. The other side of the question is that the water hammer is not excessive, and is not more than is obtained in other places. I thought if any gentleman here had known of trouble from water hammer caused by fire protection devices, it might be interesting to bring the matter up. If the difficulty is with the device, and the water hammer is something which is going to cause trouble in other places either now or later on, I think we would all like to know it. I don't know as I have made myself clear, but I was wondering whether any of you gentlemen had had experience with water hammer causing breaks, and had taken action against devices, perhaps not fire protection devices, but elevator devices, or things of that kind.

MR. WALKER. I inspected the working of an hydraulic elevator in Worcester once, and the pressure went up from three hundred pounds to one thousand pounds, due to water hammer. I told them we did n't want any such thing as that in Manchester, for water hammer on cement pipe isn't healthy. [*Laughter.*]

MR. FISKE. Do you know of any action ever being taken by any water-works company in this matter? I should think the case you mention was rather exceptional, and I refer to a moderate water hammer, perhaps of two hundred pounds.

MR. WALKER. No, I never knew of any.

Mr. Fiske. I should think the water-works people would feel like sitting down on any device which causes excessive water hammer.

Note. — As stated on page 113, the manufacturers were to hold a meeting on January 16, at which they were to formulate their position; but a statement of their views has not yet been received from them, although requested several times, and each time promised "in a few days." — Editor.

THE MARLBOROUGH WATER WORKS.

BY GEORGE A. STACY, SUPERINTENDENT, MARLBOROUGH, MASS.

[*Read February 12, 1902.*]

The first action taken by the town of Marlborough towards introducing a public water supply was in 1873, when a committee was chosen to take the matter under consideration, and they secured the services of the late Phinehas Ball, C. E., of Worcester, and reported in 1874.

This report recommended a pumping station, distributing reservoir, fifty hydrants, and about eight miles of cement-lined pipe.

The attempts to introduce a public water supply met with the usual vicissitudes common to such undertakings, until 1882, when decisive action was taken and the work commenced, and the late M. M. Tidd was retained as engineer.

The city of Marlborough is situated at a considerable elevation above the immediately surrounding country, and the west end is built in part on four hills, viz., Prospect, Fairmount, Mount Pleasant, and Sligo; the last is the highest, and is about six hundred feet above tide water, and situated in the northwest part of the built-up part of the city; it is two hundred and sixteen feet above Main Street, at City Hall.

At the southwest base of Sligo Hill, and distant about fifteen hundred feet from its summit, is Lake Williams, a natural body of excellent water, the surface of which is about forty feet above Main Street, at City Hall (see plan, Fig. 1).

Considering its elevation, the city was very much favored by nature in regard to a public water supply, with one exception, and that was the quantity, — the watershed of Lake Williams being only two hundred and nineteen acres. But as all other suitable supplies were from two and one-half to five miles distant and at a very much lower level, and as Lake Williams would in all probability furnish a supply for a number of years at a comparatively small cost, it was decided to take this supply.

A pumping station (now called Station No. 1) was built on the

north shore of the lake; a reservoir of five and one-half million gallons capacity was constructed on Sligo Hill, ten miles of distributing mains were laid, and the water was turned on Main Street, on July 1, 1883. This work, and five miles of pipe laid in 1884, was done by contract; since that time all work except Pumping

FIG. 1. — PLAN OF LAKE WILLIAMS, SLIGO RESERVOIR, AND CONNECTING PIPE LINES.

Station No. 2 and the standpipe has been done by the city with day labor.

In 1891 the low water in the lake demonstrated that we had about reached the safe limit of our supply, especially in a series of dry years.

After investigating all the available supplies and conferring with the State Board of Health, it was decided to construct a reservoir on Millham Brook in the northwest part of the city (see Fig. 2).

This brook, with its north branch, has a drainage area of about three and one-half square miles, which is very sparsely populated.

The dam was constructed of earth with a concrete core wall. It is 1 160 feet long on top, with a maximum height of twenty-six feet; the foundation of the core wall is on bed rock and in hard pan, and its maximum depth is twenty-five feet below the surface. A thirty-inch pipe extends through the south end of the dam on a level with the bottom of the reservoir.

The north end of the dam abuts on a ledge which rises from ten to fifteen feet above the top of the dam, and by the removal of about

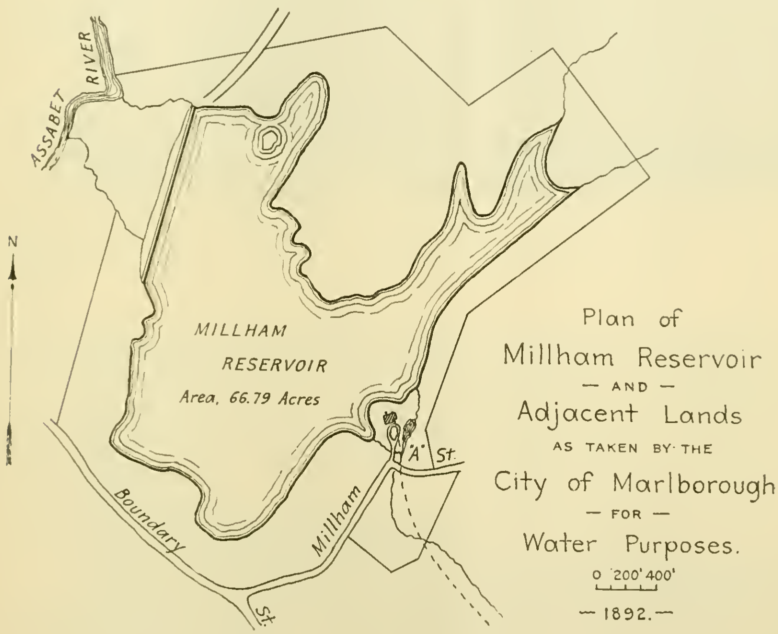


FIG. 2.

one thousand cubic yards of rock, a wasteway was cut through this ledge. Fig. 1, Plate I, is a view of the dam, and Fig. 2, Plate I, shows the wasteway.

A pumping station, called Station No. 2 (see Fig. 1, Plate II), was built on the south shore of this reservoir. In this station is a high-duty Worthington pump of two and one-half million gallons

capacity, and two boilers, sixty inches in diameter and sixteen feet long, built for a working pressure of one hundred and twenty-five pounds. The head against which the pump works when pumping to Sligo Reservoir is 408 feet.

The water of Millham Brook enters the reservoir at the point marked "*A*" on the plan, Fig. 2. Forty or fifty years ago this was the site of a small sawmill such as were common in those days, and part of the small dam only remained. As it was probable that we should be in need of more water than Lake Williams could furnish before the new reservoir was completed, advantage was taken of the situation, the old milldam was rebuilt, and a pipe about fifty feet in length was laid from the small basin thus formed to the gate chamber of the pump well, and we were able to pump a limited amount from this source in the spring of 1893.

The force main from this station is two and one-quarter miles long, passing through private land for one half of the distance, the balance being in Northboro Street and Lakeside Avenue, which passes directly in front of Station No. 1 at Lake Williams.

The force main from the latter station crosses the avenue at this point, and the two mains are connected here by a Y-branch ; between this connection and Station No. 1 is a four-way branch, with four gates controlling all the outlets (see plan, Fig. 3).

After crossing the avenue, the original force main passes north-east through private land for about twelve hundred feet, and enters the south end of Sligo Reservoir grounds, passing east through these grounds in a continual line to Broad Street (at this point it becomes the main distributing pipe) ; then south on Broad Street to Lincoln Street, then east down Lincoln Street. Lincoln Street going west forms a junction with Lakeside Avenue, near Station No. 1, as shown in Fig. 1.

From the east outlet of the four-way branch on the force main in front of this station, a pipe is laid over Lincoln Street to the junction of Lincoln and Broad streets, and connects with the main distributing pipe (see Figs. 1 and 3).

From a Y-branch on the force main in the reservoir grounds a pipe leads to the south end of the reservoir, discharging at high-water level ; at the outfall of this pipe is a flight of stone steps for the water to fall over ; there is a gate on this line, and one on the main just east of the Y-branch.

About two hundred feet east of this point, the pipe line leading

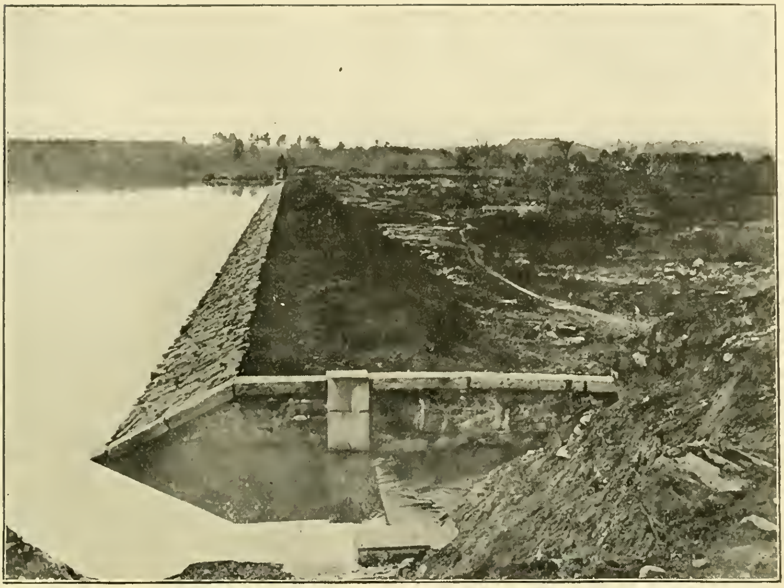


FIG. 1. — MILLHAM DAM, LOOKING SOUTH.

FIG. 2. — WASTEWAY, MILLHAM RESERVOIR.

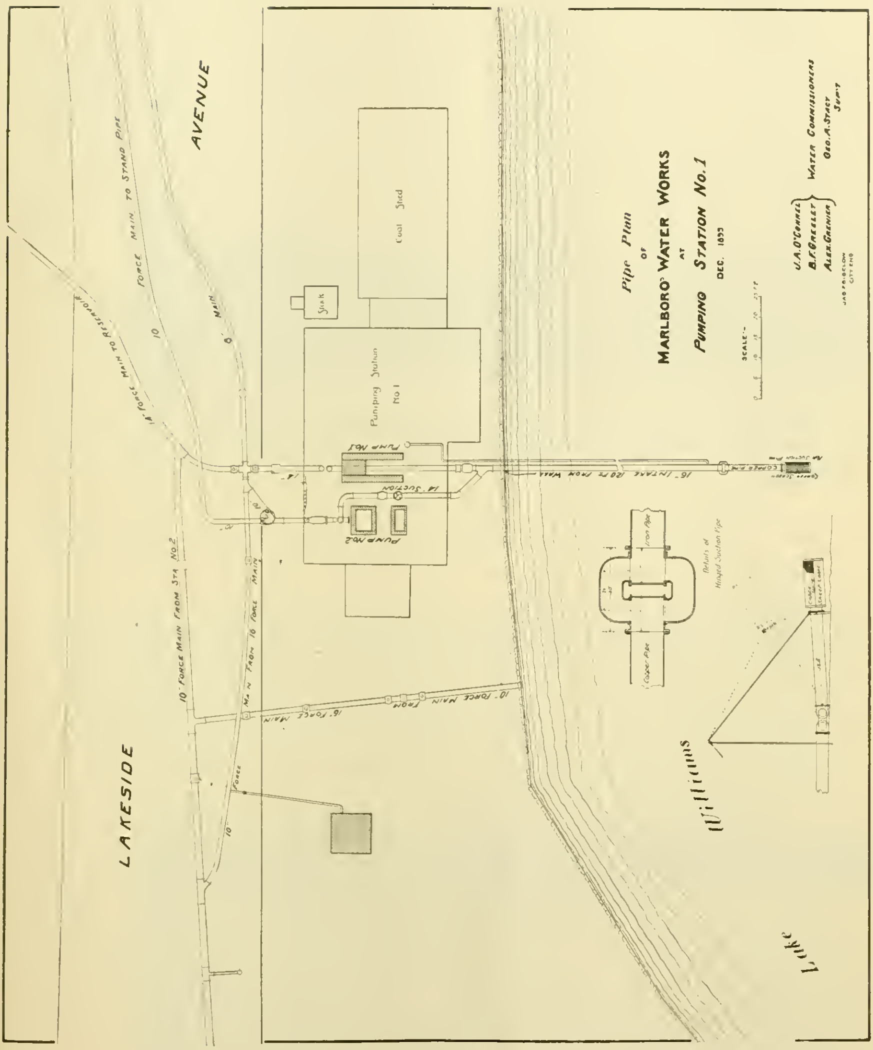

LAKESIDE
AVENUE
Pipe Plan
of
MARLBORO' WATER WORKS
at
PUMPING STATION No. 1
Coal Shed
Pumping Station
No. 1
PUMP No. 1
PUMP No. 2
14" SUCTION
16" INTAKE 120 FT FROM WALL
10" FORCE MAIN FROM STA. NO. 2
16" FORCE MAIN
10" FORCE MAIN FROM
8" MAIN
10 FORCE MAIN TO STAND PIPE
14" FORCE MAIN TO RESERVOIR
Details of
Hinged Suction Pipe
Iron Pipe
Copper Pipe
Williams
Lake
J. A. O'CONNEL
B. F. GREELEY
ALEX. GRENIER
WATER COMMISSIONERS
GEO. A. STACY
SUP'T

FIG. 3.

from the gatehouse is connected with this main, with a gate on each, set near their junction. The gatehouse is on the north end of the reservoir.

This combination of pipes and gates permits the cutting out of the reservoir for cleaning or repairs, supplying the city by direct pumping through two lines, or either one of them; it also permits the cutting out of the main on Broad Street, between Lincoln Street and the reservoir grounds, and supplying the city from the reservoir by the water passing back through the force main to Station No. 1, then through the pipe line leading from the four-way branch, over Lincoln Street, to the junction of Broad and Lincoln streets.

On the force main from Millham Reservoir, about one hundred feet west of its junction with the old force main at Station No. 1, is a Y-branch, from the outlet of which a pipe connects with the west outlet of the four-way branch on the old force main; this forms a by-pass, by which we can pump directly to the city through the Lincoln Street main from Station No. 2, as well as from Station No. 1.

From the force main of Station No. 2, between the Y-branch and its connection with the old force main, a discharge pipe is laid through the station grounds to Lake Williams.

There is a gate on this pipe, and one on each side of the branch from which it is taken; this pipe is used as a blow-off, and by opening and closing the proper gates, the water in the distributing reservoir can be drawn off into the lake, and at the same time the city can be supplied by direct pumping from either station through the main on Lincoln Street; it is also used when pumping from Millham Reservoir to Lake Williams.

If the water in Lake Williams is at high-water mark in the spring, it will furnish a supply for the season; and to accomplish this the pumps at Station No. 2 are run in the winter and spring (when the water at this place is at its best) until the amount pumped to Lake Williams, together with what it receives from its own watershed, assures this result. Station No. 2 is then put out of commission for the balance of the season, or until such time as an additional supply from this source is needed.

These conditions had an influence on the treatment given to the bottom of Millham Reservoir at the time it was built.

The shores of the reservoir are mostly steep, as shown in the view, Fig. 2, Plate II, and with but little shallow flowage; about

FIG. 1. — PUMPING STATION NO 2.

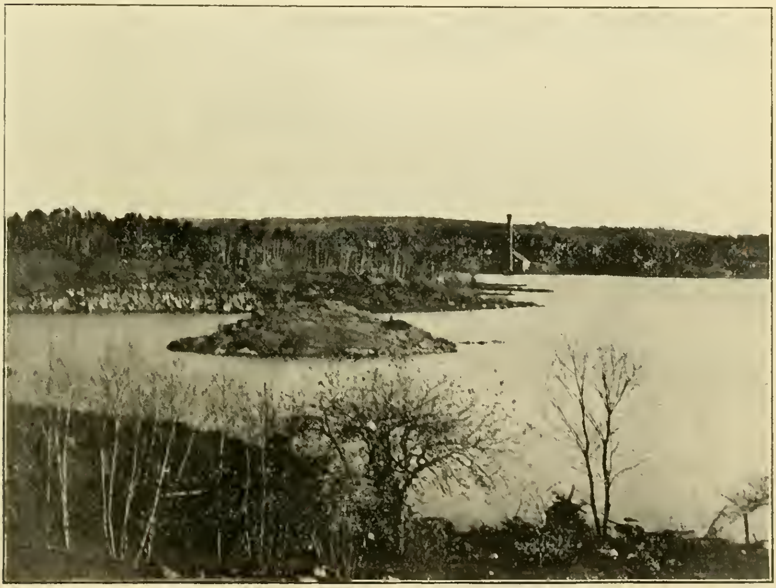


FIG. 2. — MILLHAM RESERVOIR LOOKING SOUTH.

sixty per cent. of the bottom was meadow land, and along the course of the brook that flowed through it, the mud in places is quite deep; the balance of the basin was woodland.

Plans for stripping the whole basin were considered, as well as for covering that part where the mud was deep with sand and gravel taken from the hills that formed a large portion of the south shore of the reservoir.

The estimated cost of stripping the whole basin made by our engineer was from seventy to eighty thousand dollars.

The question of filtration was also considered, and it was thought possible that in the near future the advancement made in the construction and introduction of filters in this country might be such that this money, expended in filtering the water from all sources as it went to the consumer, would yield the greater benefit.

It was then decided for the present to strip only the surface from high-water mark out to a point where the water would be ten feet deep with a full reservoir, and to fill the shallow places with the material thus removed.

Under these conditions, using Lake Williams in part as a storage reservoir, we are able to select the best and most convenient time to pump from Millham Reservoir, and we have up to the present time secured a very satisfactory supply from this source; and the saving in interest has amounted to twenty-five per cent. of the estimated cost of stripping the balance of the basin.

The force main from Station No. 2 is laid to a hydraulic grade to within one-half mile of Station No. 1, where it reaches the summit; from this point to the station, at the point where the blow-off pipe discharges into the lake (Fig. 3), the fall is forty feet.

There is a considerable population along this line where it lies in the highway which is supplied from this force main, and when pumping into Lake Williams sufficient back pressure has to be maintained at the discharge pipe to supply the services on the summit.

At first, to accomplish this, the gate on the discharge pipe was partly closed, but we found that it was difficult to adjust this gate just right every time; and there was another difficulty, if not danger, in this method, for if, when the pumps were stopped, this gate was not immediately closed, the discharging water would cause a strong siphon action on the summit, and possibly draw air in through the service pipes, and cause trouble when the pipes were filled again.

As a secondary means to avoid this, a specially designed automatic gate was tried. but this proved a total failure.

I then designed the siphon now in use, which was constructed by inserting two three-way branches in the discharge pipe, where it passes through the station yard, spaced eight feet on centers, with the outlets on top, and with a gate set between them. Pipes rising two feet above the surface with flanges on top were set in these branches. The siphon is bolted to these flanges, and is constructed of spiral riveted galvanized iron pipe, and is forty feet high, or a little above the grade of the force main at the summit. A view of this siphon is shown in Fig. 1, Plate III.

A vertical check valve, inverted, was placed on the top of the elbow of the discharging leg of the siphon, to act as an air valve.

By closing the valve between the three-way branches, the water flowing to the lake must pass over the siphon, and this affords a free passage for water and a constant head, and the pumps at Station No. 2 can be stopped and started without danger to the pipe line.

When the pumps at Station No. 2 are stopped for the day, the gate near the main, on the discharge pipe, is closed, and the gate on the force main opened, thus connecting this line with the distributing system, of which it is a part at all times when the pumps at Station No. 2 are not running.

In cold weather, to prevent the siphon from freezing, the gate between the two three-way branches is opened, allowing all the water to drain into the lake.

Previous to the introduction of a public water supply, Marlborough had relied upon hand engines and small reservoirs for portection against fire.

After the water works were in operation, the hand engines were put out of commission, and the water for the extinguishment of fires was taken directly from the hydrants.

In 1894 the growth in the number and size of the factories, and other private and public buildings on the higher levels in the west part of the city, was such that the water pressure did not furnish adequate protection for that district, and steps were taken to improve this service.

The first cost, cost of maintenance and efficiency of steam fire-engines, and of an independent pipe system supplied by a standpipe, were considered, and it was decided in favor of the standpipe system ; and work was immediately begun upon its construction.

FIG. 1.—PUMPING STATION NO. 1, AND SIPHON.

FIG. 2.—VIEW OF STANDPIPE AND SLIGO RESERVOIR, FROM THE SOUTH SIDE OF LAKE WILLIAMS.

This fire service consists of a standpipe, three miles of fourteen-, twelve-, ten-, and eight-inch pipe, thirty-two hydrants, and a Barr compound condensing pumping engine of about one and one-half million gallons capacity.

The engine was erected in Station No. 1 at Lake Williams.

The standpipe is located on Sligo Hill near the south end of the distributing reservoir; the tank is thirty feet in diameter and thirty-five feet high, with a conical bottom, and has a capacity of two hundred thousand gallons. A view of the standpipe is shown in Fig. 1, Plate IV. It may be seen in the distance in Figs. 1 and 2, Plate III. It is constructed of iron, with the round-about seams single riveted, and the vertical seams double riveted for the first fifteen feet. The conical bottom is made with butt-strap joints, with the butt straps on the inside, double riveted. A flange is turned up on the outer edge of the conical bottom plates, and is double riveted to the bottom sheets of the tank, and also to the steel channel plates that surround the bottom of the tank on the outside. This channel is riveted to the top of a plate girder three feet deep, which is riveted to the heads of ten steel columns seventy-two feet high. A twelve-inch vertical pipe connects the tank with the ground main, and is protected with a double wooden jacket, with six-inch air spaces; the inside jacket is covered with hair felt one inch thick, which is held in place by brass bands.

A balcony surrounds the top of the tank, which is one hundred and ten feet above the ground.

The roof is cone-shaped, and the extreme height is one hundred and forty-six feet; situated on this elevation, it is a very prominent object.

The standpipe was designed by B. R. Felton, then city engineer of Marlborough, with F. C. Coffin as consulting engineer, and was built by Tippett & Wood, Phillipsburg, N. J. It has never cost a cent for repairs, except for the necessary painting, and is absolutely water tight.

It was the second one of this shape erected, and although smaller, was similar in appearance and design to the standpipe that fell at Fairhaven a short time ago.

This service is for fire protection only, and was designed to deliver ten $1\frac{1}{8}$-inch effective fire streams at any point on the system.

At a test made in April, 1894, ten $1\frac{1}{8}$-inch streams were used, the average length of hose to each line being two hundred and fifty feet. A gage, set on one nozzle of a four-way hydrant to which

three of the ten lines were attached, showed a loss of pressure varying from six to seven pounds. The static pressure at this point is eighty pounds, and the streams were thrown higher than the flagstaff on the four-story factory, at which the test was made (see view, Fig. 2, Plate IV).

The power and volume of the streams shown at this test, and at others made on different parts of the system, demonstrated to the citizens who witnessed them that this district had now an ample fire protection, and that it would take at least five steamers such as are used in cities of the size of Marlborough to duplicate this work.

To prevent this system from becoming useless by any possible accident or conditions that would cut off the supply from the standpipe or pumps, a connection was made between the standpipe and reservoir mains, at the reservoir grounds; a check valve was set in this connection, and a gate on each side of it.

Every manufacturing establishment in the city, with two exceptions, is protected by sprinklers.

In the district covered by the standpipe service, the sprinklers are connected to both systems; and to prevent the water flowing from the high to the low service, a check valve, enclosed in a manhole at the sidewalk, is set in the pipe that connects the sprinkler system with the reservoir service.

At first I had some doubt as to these check valves working satisfactorily under all conditions, but up to the present time they have never caused any trouble; they open freely and close tightly.

There being no water drawn from the standpipe except in case of a fire, except that due to leakage or the breaking of a sprinkler head once in a while, it was thought necessary that some method be adopted to prevent it from freezing. For this purpose the force main of the reservoir and that of the standpipe were connected in the basement of Station No. 1 by a one and one-half inch pipe, controlled by a gate valve; the difference in pressure on the two mains is fifty pounds, and upon opening this valve the water flows from the standpipe to the reservoir main and thus keeps up a circulation. When the water in the standpipe is drawn down about three feet, it is pumped up again.

That this was a necessary precaution was shown by a little incident that happened the second winter it was in operation.

One cold Sunday morning I was called up to the station, and the engineer informed me that the night before when he pumped up the

PLATE IV.

FIG. 1.—SLIGO RESERVOIR AND STANDPIPE.

FIG. 2.—TEST OF FIRE STREAMS FROM STANDPIPE SERVICE.

standpipe he closed the valve on the by-pass (as was usual at that time), and forgot to open it again, and as the gage on the Barr Pump showed only reservoir pressure, he was afraid the standpipe was frozen up. Opening the relief valve and getting no response from the tank proved that this was so.

After carefully considering the matter, I concluded that the first place to freeze would be where the top of the wood jacket butts against the conical bottom, the cone being of small diameter at that point and unprotected, and its shape would be favorable to the removal of any obstruction by pressure applied underneath. Believing that the pipe lines were perfectly safe at two hundred pounds, I decided to try the experiment of forcing the ice up.

Starting up the pumps, I slowly raised the pressure on the force main until the gage showed one hundred and forty-five pounds, after which it slowly dropped back, and the pumps began to speed up, and I then knew that I had broken the ice, or something else. It proved to be the ice; and we have never had any trouble from that cause since.

It is now a standing order that the valve on the by-pass shall never be closed, from the time it opened in the fall until it is closed for good in the spring.

A Winslow recording gage is used to indicate the height of water in the standpipe, and has never failed to work satisfactorily.

The works at this time consist of two storage reservoirs with all their tributaries and water rights, with an aggregate storage capacity of about eight hundred million gallons, and four square miles of tributary watershed; two hundred and twenty-five acres of land from which we removed a number of dwellings, barns, outbuildings, and ice houses — and the city now owns and controls all the land around its reservoirs, and has paid, for land, land damage, and water rights, over one hundred thousand dollars; a distributing reservoir of a capacity of five and one-half million gallons, and a standpipe holding two hundred thousand gallons, both of these situated in Reservoir Park, on Sligo Hill.

The view from this place is unsurpassed in this section, the land sloping away in all directions to the surrounding valleys, in which are located a number of towns.

To the naked eye, the view extends from Mount Monadnock, in New Hampshire, on the north, to the Blue Hills of Milton on the south; from Bunker Hill Monument on the east, to Rutland, called

the center of the state, on the west; and, with a telescope, forty-five towns and villages, and a number of reservoirs and standpipes, can be seen.

The works also include Pumping Station No. 1, which contains two eighty horse-power boilers, one two-million Blake, and one one and one-half million Barr compound condensing pumping engine; Station No. 2, with two eighty horse-power boilers, and a two and one-half million Worthington high-duty pumping engine; 37 miles of distributing pipe; 344 hydrants, with a pressure of from 30 to 142 pounds; 386 gates; 1 200 meters, and 2 250 services.

The net cost of construction has been $586 645, and the net debt is $372 251.

The original works were designed by and constructed under the late M. M. Tidd, C. E., and the Millham supply and standpipe system by B. R. Felton, then city engineer of Marlborough.

During the nearly nineteen years of operation, the works have met every demand made upon them in a most satisfactory manner, and have proved an excellent example of water-works construction as produced by the engineers of to-day.

THE DECISION IN THE DAYTON ELECTROLYSIS SUIT.

[*Reprinted from "Engineering News" of April 17, 1902.*]

A partial victory has been won by the city of Dayton, Ohio, in its electrolysis suit against the City Railway Company. Mr. O. B. Brown, judge of the Court of Common Pleas of Montgomery County, has refused to order the street railway company to install the double-trolley system, as urged by the city, but says the company has been negligent in the operation of its road and must conform to the best standard practice of operating single-trolley lines.

The trial was a lengthy one, the experts were numerous, and there were many exhibits and several experiments before the court. The decision of Judge Brown occupies two full pages of the Dayton *Herald* for April 5, 1902. A large part of the opinion deals with purely local questions, and the findings of the court hinge largely upon the nature of the franchise granted by the city to the street railway company. The decision, therefore, has only a general bearing upon the electrolysis question in other cities, and, it is to be remembered, is subject to review in the higher courts.

After a detailed review of the contentions of the city and the company, and of the law on the subject, the judge concludes that a contract existed between the city and company "for the construction, operation, and maintenance of a single-trolley electric railroad."

Another point made by the judge was that the city had never attempted to compel a change in the method of traction by the exercise of its police powers, and that the court had no authority to exercise such power. For this and other reasons the judge held that even if the facts showed that the double-trolley or the underground conduit system was the only method of preventing the destruction of the water mains by electrolysis, yet the law would not permit him to order the adoption of one or the other mode of traction.

The first trolley line in Dayton was installed in August, 1888, "but the present system of operation did not become general until the early nineties." The first line, it appears, was owned by a company other than the defendant in this suit, and the first noted instance of electrolysis was upon a lead service-pipe, near this same early line,

found in 1893. That same year, Mr. Charles E. Rowe, secretary of the Dayton water-works, was sent to the Milwaukee meeting of the American Water-Works Association, where, the judge says, "The question of the electrolysis of water pipes was first publicly discussed."

Both sides to the suit admitted that the water pipes of Dayton are being damaged by electrolysis, but they did not agree as to the extent of the damage. During the trial a six-inch water main broke, when, in the course of a fire, the pressure was raised from sixty to one hundred pounds. The broken pipe was, the judge says, —

> brought into court the following morning and examined by the experts for the first time in court. This showed that the pipe had been badly eaten away throughout its entire length by electrolysis; and indicated to the experts that the current was pretty uniformly distributed over the surface.

Rivers, canals, steam railways, and intersecting street railway lines, the judge says, conspire to make the return of the electric current to the power house unusually difficult in Dayton.

All the experts in the case testified that the defendant had operated its railway "in a very inefficient and negligent manner, and far below the present standard of the art." The bonding is very inadequate throughout. In fact, a chart introduced by the defendant raises "a doubt as to there being any good bonds on most of the system." The experts also agreed that the system of return feeders in use "is not sufficient for the economical and safe operation of the" railway. The ground plates in use are no longer considered good engineering.

The balance of the opinion, with the summary of findings, is given substantially in full, as follows: —

> The testimony in this case shows that the plaintiff is powerless to adopt any method whatever to protect its piping system. On the other hand, a single-trolley street railroad, such as the defendant operates, can adopt no method by which the tendency of the current to flow through the earth and on to the pipes can be entirely overcome. But I am of the opinion that by coöperation between the two, such a system could be adopted as would reduce the injury resulting from electrolysis to a minimum or negligible quantity, as the experts term it.
>
> The defendant claims, however, that no system would prove effective as long as the other roads continue to operate as they are, but the testimony shows that any preventive measure adopted by this company would reduce the liability to injury to that extent.

The rails should all be metallically connected by adequate bonding, and the bonding well inspected frequently, and heavy copper cables should be used to conduct the current across the bridges and under the steam railroad crossings and intersecting railroad tracks. Return feeders of sufficient conductivity should connect the rails at various points to the negative bus-bar of the dynamo. This would increase the conductivity of the rail path and induce a much greater quantity of the current to flow thereon.

The ground plates which are still in use by the defendant should be removed, thus reducing the tendency of the current to flow to the underground metallic structures.

Having corrected the system by proper bonding, and by proper rail return, there should be coöperation on the part of the water-works board in permitting to be placed, as may be determined, at the proper places, the necessary insulators in the piping system. A few or none may be required.

A system operated along these lines, without insulators or pipe connections to the rails or dynamo, has proven successful in Hartford, Conn., and in other cities where the conditions are somewhat similar to those existing in this city.

The officials of the city of Chicago have also acted upon this theory, and have passed an ordinance making it unlawful for "any person, firm, or corporation, owning, operating, or controlling any surface or elevated railroad or any street railway within the city of Chicago, upon which cars are now or hereafter operated, by electricity as a motive power, with a grounded return circuit for conveying electricity," to operate their system without a "metallic return circuit of such cross-section and conductivity for conveying the current so used as a motive power, that the maximum difference of potential will not at any time exceed one volt between any part of such metallic return circuit and any water pipes, gas pipes, or other metals not installed for the purpose of forming a part of such metallic return circuit, and that there will not be a variation in difference of potential exceeding one-half volt, between any two measurements made at the same time at points along and upon said metallic return circuit, within a distance of three hundred feet or less from each other."

Similar regulations have been made in other cities in this country, and general regulations have been adopted by the different British boards of trade and by what is known as the Bristol Tramways Act, and it is now generally considered by practical and scientific men that if a difference of potential not higher than about one and one-half volts is maintained in the positive district, and difference of potential not higher than about four volts in the negative district, the pipes will be practically immune from damage.

I am satisfied, from a careful consideration of all the testimony, that if these remedies are applied with intelligence, according to the present state of the art, it is possible to establish and maintain, by careful and frequent inspections and electrical measurements, such a return for the current of the City Railway Company as will practically protect the water pipes of the city, and be also a great saving to the railway company in the cost of operation.

SUMMARY OF FINDINGS.

Upon consideration of the entire matter, I have come to the following summary of conclusions as to the law and facts: —

This court has no authority in law to compel a change in the system from the single trolley to the double trolley, and, if the same was warranted by the law, the facts would not justify such a change.

The defendant has been and is operating its road in a negligent manner, causing continual damage to the water pipes of the plaintiff, for which the plaintiff has no adequate remedy at law, and cannot by any practical method prevent such damage.

It is no excuse in law, and the facts would not justify the defense that other electric lines in Dayton are contributing to this or doing like damage. (Spelling, Sects. 390–397. McClung *v.* North Bend Coke Co., 9 C. C. 259. Meigs *v.* Lister, 23 N. J. Eq. 199.)

It is therefore the duty of the court to enjoin the defendant from so operating its railway, and to compel it, within a reasonable time, to introduce such improvements in the system, in order that the operation of the single-trolley system authorized by the franchise and contract will be in accordance with the present standard of the art of operating single-trolley roads. The plaintiff shall coöperate to that end.

All matters of detail can be arranged between counsel and the court in the final order.

The costs will be adjudged against the defendant.

After the foregoing decision was rendered, counsel for the railway company addressed some remarks to the court, in which it was virtually stated that if the city would let the case stand, without appeal, it would do the same, and, of course, would also comply with the orders just given.

EDITORIAL DISCUSSION IN "ENGINEERING NEWS."

The decision in the Dayton electrolysis suit, reviewed at some length above, while in some respects disappointing to the water and gas fraternities, is nevertheless a signal victory for both the city of Dayton and municipalities at large. The decision recognizes, (1) that trolley currents improperly returned to the power house destroy water mains; and (2) that even when a street railway company has a contract with a city for a single overhead trolley system it must use every well-recognized means to keep its currents off the water and gas mains. The city fought hard to secure an order for a change from the single to the double overhead trolley system, or else to the underground conduit system. This, we think, was a mistake. We have always maintained that it is not the duty of a city to say how elec-

trolysis shall be prevented. The burden should rest wholly with the street railway companies. When a city attempts to say how the problem shall be solved, it assumes more or less responsibility for the success or failure of the remedy. It may even find to its sorrow that it has entered into a contract, and has thus debarred itself from otherwise possible relief. In the Dayton decision, the judge virtually declares that no matter how dangerous the menace from electrolysis, nor how effective a remedy might be found in the double overhead trolley system, the city cannot force the adoption of the latter because it has entered into a contract for the single overhead trolley. In the future, cities will do well to see that their street railway franchises do not cut them off from relief from damages to their own property. In addition, no street railway franchise should be granted hereafter which does not specifically provide that the system shall be so constructed and operated as to return the current to the power house without menace to underground furniture and without any other danger to life or property.

INVESTIGATIONS IN REGARD TO COLORING MATTER IN WATER AND METHODS OF REMOVAL.

[*Discussion, March 12, 1902.*]

President Merrill. The first paper announced upon the program for the afternoon is by H. W. Clark, chemist, Massachusetts State Board of Health, on "Investigations in Regard to Coloring Matter in Water and Methods of Removal." I am sorry to tell you that a telegram has just been received from Mr. Clark announcing that he is too ill to be present with us to-day. We are very fortunate in having here, however, one of our members who is familiar with this subject, and it gives me great pleasure to call upon Mr. Desmond FitzGerald at this time.

Mr. Desmond FitzGerald. Mr. President and fellow-members: I think it is little short of torture to be brought back at a second's notice from the old "Suwanee River" — where, under the spell of the sweet voices of our quartet, I was paddling down the stream in a canoe, thinking of the "old folks at home" who were waiting to welcome me to the cabin — and be asked to address a public assembly. [*Laughter.*] And yet I think I ought to thank our President for not having given me notice before the dinner began that I was to be called on, for, while in blissful ignorance of what was to follow, I have been able really to enjoy myself up to the present moment. The fact is, I always do enjoy these dinners of the New England Water Works Association very much, and I regret that it is not possible for me to be here oftener. As I look around the tables I notice some changes and a number of new faces. The most surprising change is in the head covering of some of our members, which seems to have become of a purer *color* as time has gone by, — partly accounted for, perhaps, by the fact that it is twenty years ago that the New England Water Works Association was organized.

While, as I have said, I am always glad to be here with you, I have sometimes thought I would never come to one of these public dinners again, because it always seems to fall to my lot to fill some gap. I know we all anticipated the pleasure of listening to Mr. Clark's paper, and it is a disappointment that we are not to hear it.

As I look around I see others here who could take Mr. Clark's place much better than I can, Mr. President. However, I presume something is expected of me now, and perhaps it may be of interest if I briefly review some of the history of this subject.

I remember very well that when the whole of Boston's supply came from Lake Cochituate there were no complaints about the color of the water. The color of the Cochituate water was about .25 to .30 on the Nessler scale. There were a good many complaints about the water in those days, however. Sometimes people could not brush their teeth with it, but that was n't a very serious thing, — they could get along without that, perhaps; sometimes they did n't want to bathe in it, and sometimes they certainly did n't want to drink it — but the color was all right. When the Sudbury River water was introduced for the first time, in 1872 or 1873, the works being completed from 1875 to 1878, that water was highly colored. I may remark, by the by, that the only reason why the Cochituate water was a light colored water was because it came from a lake so large in proportion to its watershed that the water became decolorized, or largely decolorized, by storage. We all know about that now, but we did n't seem to know so much about it in those days.

For a number of years we have been taking the colors of the waters in the brooks which feed the lake, and we know that the average color is something over 1.00 on the Nessler scale. That is reduced by storage to about .30. Then the Sudbury water came in from three small basins, in the first place, with a drainage area of about seventy-eight square miles, and that water was up to .70 and even higher, while the average color of the water running in the river was perhaps 1.00, as I remember it, about the same as that running in the brooks feeding Lake Cochituate. But of course we had to supply that water to the city at a very much higher color than the Cochituate, and people complained of it.

Now, I lay a great deal of stress on this matter of getting rid of the color in water, and it seems surprising to me to listen to the opinions of some people on this question of pure water, good water, that you are not ashamed to pour into a glass. For instance, look at the situation in Brockton to-day. There is a splendid great city, with intelligent men in it [*laughter*], and yet to-day they stick at the point of getting a first-class water, with almost no color, because it is going to cost a little more than a highly colored water. And there is that same fight right along that line almost everywhere.

Brockton can get the water of Silver Lake, which is a perfectly splendid supply, and you would think they would jump at it.

One step has led to another in the investigation of this subject, and we have made a careful study of it because it was so important in the city of Boston. I think I had the honor of conducting almost the first observations on an extended scale that were made in this line. The color of the water in the basins, brooks, and swamps on the Sudbury watershed was taken at many points every week for many months, and tabulated. We found that the water as it comes from the hills, before going into the swamps at all, has very commonly a color of .20 or .25 before it is brought in long contact with vegetation. We found that the water flowing from some of the hills surrounding Cedar Swamp, for instance, had a color of .25 and that after being held in the swamp, it would run up to 3.00 or 4.00. That led to the conclusion that the great cause of the high color in the Sudbury water was its being held in the swamps. Some of it comes from iron, but I think that for our purposes here to-day we may practically ignore the question of iron as giving color to the water. That part of the subject has been considered in great detail in some of the Boston Water Works reports, and owing to its complications need not be referred to here. It may be stated as a general rule that New England waters get their color from swamps.

Our investigations led us to the adoption of a scheme for draining the swamps, which was formulated in a report I made to Mr. Stearns and contained in the State Board of Health report on a Metropolitan Water Supply, 1895. It is rather interesting because it was something new in those days. The question to be solved was, What will be the effect on the color of the water if the swamps are partially drained? My estimate was that, by carrying out a certain system of draining and interception, the water would be reduced forty-two per cent. in color.

That system has been carried out on the Metropolitan Water Supply. I don't know exactly what the result has been on that part of the works which Mr. Richardson has charge of, but, on the part that I have particular charge of, the color has been reduced just about forty-two per cent., as far as I am able to say now.

Now, by filtration in the ordinary way in open filter beds, by the slow process of sand filtration, I have found by experiments during three years at the Chestnut Hill Reservoir, that, on the average, you can practically reduce the color of the water about twenty-five

per cent. I am not going to say anything about the chemical side of the question, because there are others here who can speak of that much better than I can. Now, it seems to me, Mr. President, considering that a gentleman is here with an admirable paper, which you are all anxious to hear, that I have said enough. If there are any questions that any one would like to ask, I would be happy to try to answer them, and perhaps some one would like to take up the matter and carry it along further.

I will say one word more on the question of storage. In this very arge reservoir at Clinton, which Mr. Stearns is building, I suppose the color of the water will be reduced to such an extent that it will practically not be noticed at all, because the water will be held in a large lake for about a year, and in that time almost complete decolorization is expected to take place. It has always been a delight to me to go to some large lake, like Lake Winnepesaukee, and see how absolutely pure in color the water is. But, if you walk around the shores of the lake, you will find the streams entering the lake are often very highly colored. The removal of this color is of course due to long storage, and that is what we are trying to do in building such large reservoirs, — to hold the water and store it long enough to get rid of the color as far as possible.

But it is not always practicable in small works. The resources for doing so are not always available, and I have sometimes thought that a good deal could be accomplished on some of these smaller works by turning some of the feeders on to large areas of gravel. I have seen situations where the erection of a small diverting dam would turn the water on to gravelly areas, through which it could percolate to the water tables below and then flow into the stream again, a very much whiter and purer water. I only throw that out as a suggestion. There are other ways. There are ways of turning a brook on to small areas of gravel and then sinking pipes and taking the water out from below. But I see I am getting into a very wide field, and so, thanking you, gentlemen, for your attention, and assuring you of my pleasure at being here with you again, I will give place to some one else. [*Applause.*]

The President. This is an interesting subject, gentlemen, and I trust it will bring out a full discussion. Mr. FitzGerald has referred in a word to the chemical side of the question. There is a gentleman present this afternoon who can perhaps give us some information from that standpoint, and I will ask Mr. R. S. Weston if

he will speak on the chemical side of the removal of color from water.

Mr. R. S. Weston. Mr. President, and members of the Association: This is the first meeting of the New England Water Works Association that I have attended for a year and a half, and I almost think that I am entitled to be allowed to enjoy it without interruption.

I have done a little work on the treatment of color in water, largely laboratory work, this last year in New Orleans. As you know, the Mississippi River comes down from the country above, bringing large quantities of silt and a large amount of vegetable matter, trunks of cypress and other varieties of trees. In the course of ages the whole delta on which New Orleans is situated has been built up in this way. If one bores a well about one thousand feet deep or less at New Orleans, one obtains water which has a color of from three hundred or four hundred to eight hundred or nine hundred parts per million. This water is quite alkaline. The treatment and removal of the color in it is something which is very difficult.

In the consideration of the question, namely, which would be the best source of water supply for the city of New Orleans, it was necessary, in order to satisfy certain elements of the population, to consider the question of an artesian well supply, and, in connection with that, one had to consider, more or less, the problem of the removal of this color from the well water. It was found that the only way to treat this highly colored water which is possible at the present time is to add sulphate of aluminum, allow the water to coagulate for some time, and then remove the cogulated masses by filtration. The ordinary colored water of New England — soft water — can be treated with about two to two and a half grains of coagulant to each gallon of water, for every one hundred parts per million of color to be removed. But in New Orleans we find that this ratio has to be multiplied several times in order to obtain the same result. The removal of color from water which is very alkaline, that is, which contains lime salts or sodium carbonate, is a matter of considerable difficulty. It is also found that if one neutralizes the alkali in the water before one adds the coagulant, a very much smaller amount of coagulant is necessary to treat the color. About the same amount of coagulant is required to remove the color of this water which has been neutralized as is required to treat waters in New England which need not be neutralized.

The following results of experiments made at New Orleans may be of interest: —

Results of Experiments upon the Decolorization of Highly Colored Waters from Deep Wells at New Orleans.

Sample.	Parts per Million.		Grains per Gallon of Sulphate of Alumina.		
	Alkalinity.	Color by Platinum Standard.	To Decolorize: Original Water.	To Decolorize: Water after Neutralization.	To Effect a Beginning in Color Removal from Original Water.
A	412	190	13	3.0	10
B	365	200	5	0.5	3
C	420	120	7	1.2	5
D	403	350	7	2.5	5
E	441	180	18	3.0	6

I think this subject of color removal is a very interesting one, and one which really ought to be studied in an experimental way somewhere and for some time. We have data now from all over the country with reference to suspended matter in streams, which are sufficient in almost all cases to enable an engineer to design a filtration plant which will meet the local conditions without much chance of failure. But the data necessary to design a plant which will remove color under all conditions successfully are not yet at hand.

One very peculiar thing about the color of the water, of the Southwest especially, is the way it is removed from solution by contact with suspended matter. I don't know of any other way to express it. For example, the water of the Yazoo Valley, and the water of all those small streams which empty into the Mississippi from Cairo down to New Orleans, is highly colored. It is more highly colored, perhaps, than that of any of our New England swamp waters, the flat nature of the country allowing a longer contact between the water and the organic matter contained in the swamps. When the water emerges from these rivers it is very highly colored, but in a short time after it has mixed with the Mississippi, along with the large amount of silt which is borne down from above, its color disappears entirely. The color is absorbed by the silt, and

the organic matter, which is found by analysis to be present in a dissolved state in the tributaries, is found in a suspended state in the water of the main river itself. The color of the Mississippi water, after the suspended matter is removed, is practically zero, while the color of these tributaries is as high as eight hundred or nine hundred units.

There is a misconception, I find, all over the country, with regard to the meaning of the terms "color" and "turbidity." I think it is best to consider the color as that which is not readily removed by straining. The vegetable stain or color is what produces the tea-like appearance of water, while the turbidity is that which offers resistance to the passage of light, — that is, suspended matter. Mr. Hazen and Mr. Whipple, as you all know, have been lately doing some work for the United States Geological Survey, and have devised two very convenient, portable, and simple pieces of apparatus for determining color and turbidity. I will not attempt to describe these pieces of apparatus, for they will be described very soon in a bulletin of the Hydrographic Department of the Geographical Survey.* It is to be hoped that every superintendent of water works will get these pieces of apparatus and make observations of color and turbidity for the common good.

The President. I will call upon Mr. C.-E. A. Winslow.

Mr. C.-E. A. Winslow. I do not believe I can add anything to what has been said. I have been very much interested in what Mr. FitzGerald has reported about removing color by filtration through sand. From his results it would appear that the importance of that method of color removal has been underestimated. Considerable attention has been paid to the effects of storage and sunlight, but data with regard to the effect of filtration on highly colored waters are not abundant. The Lawrence filter, which effected a reduction of only 15.4 per cent. in 1893, falling pretty steadily to 8.3 per cent. in 1899, does not furnish a general precedent because the initial color of the water is so low. I hope that, somewhere, more experimentation will be done along this line and additional observations published.

The President. The subject is now open for general discussion.

Mr. F. N. Connet. It is possible that Mr. Weston refers to the apparatus I am about to describe, and it has so many good features that it is well worth our attention. It consists of two aluminum

*Circular No. 3, Division of Hydrography, U. S. Geological Survey. — Editor.

tubes, each two hundred millimeters long, and fitted at each end with caps of clear glass. One tube is filled with the water whose color is to be tested, and the other is filled with distilled water. The latter tube has a little spring clip at one end for holding a disc of slightly colored glass. A number of colored glasses of various thicknesses is provided, and it only remains to select the proper thickness so that when the observer looks through both tubes simultaneously, the color will be the same. The glass discs are all numbered to correspond with standard platinum solutions.

When the water to be tested is highly colored, it is observed through a tube only one hundred millimeters long, and when it is still more highly colored it is observed through a 50-millimeter tube. Extremely high-colored water should be diluted a known amount before testing.

This device affords a convenient, portable, and unchangeable method of measurement, and there is no possible error as to the color of the standard, as there sometimes is when the solutions are made up with platinum salts from different manufacturers.

This device was perfected by Mr. Allen Hazen, of New York City, and I think he designed it originally for the United States Geological Survey.

PROCEEDINGS.

March Meeting.

Young's Hotel,
Boston, March 12, 1902.

President Frank E. Merrill in the chair.

The following members and guests were in attendance: —

Members.

L. M. Bancroft, E. C. Brooks, G. A. P. Bucknam, George Cassell, G. F. Chace, E. J. Chadbourne, J. C. Chase, J. W. Crawford, A. O. Doane, H. P. Eddy, J. N. Ferguson, Desmond FitzGerald, W. E. Foss, F. L. Fuller, Albert S. Glover, F. W. Gow, F. E. Hall, J. O. Hall, J. C. Hammond, Jr., H. G. Holden, J. L. Howard, J. William Kay, E. W. Kent, Willard Kent, C. F. Knowlton, A. E. Martin, W. E. Maybury, Frank E. Merrill, L. Metcalf, H. A. Miller, F. L. Northrop, J. B. Putnam, W. W. Robertson, C. M. Saville, E. M. Shedd, C. W. Sherman, H. O. Smith, J. Waldo Smith, G. A. Stacy, J. T. Stevens, H. L. Thomas, R. J. Thomas, W. H. Thomas, D. N. Tower, G. W. Travis, W. H. Vaughn, C. K. Walker, R. S. Weston, C.-E. A. Winslow, G. E. Winslow, E. T. Wiswall.

Associates.

Builders' Iron Foundry, by F. N. Connet; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; M. J. Drummond, by Lester E. Wood; Hersey Mfg. Co., by Albert S. Glover; Henry F. Jenks; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by S. F. Ferguson; National Meter Co., by J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Norwood Engineering Co., by W. N. Hosford; Perrin, Seamans & Co., by James C. Campbell and Charles E. Godfrey; A. P. Smith Mfg. Co., by W. H. Van Winkle; Union Water Meter Co., by F. L. Northrop and C. L. Brown; United States Cast Iron Pipe and Foundry Co., by John M. Holmes.

Guests.

Nelson E. Bryant, Shanghai, China; W. H. Greenwood, Boston, Mass.; C. B. Russell, S. E. Jackson, A. F. Hall, George P. Hall, L. M. Hudson, Marlboro, Mass.; J. F. Gleason, Quincy, Mass.

The Secretary read the following names of applicants for membership, the applications having been approved by the Executive Committee: —

For Resident Member.

J. S. Chase, Hartford, Conn., Secretary Hartford Water Board; Samuel P. Senior, Bridgeport, Conn., Engineer and Superintendent Bridgeport Hydraulic Co.; William H. Hart, Bridgeport, Conn., Assistant Engineer, Bridgeport Hydraulic Co.

For Non-Resident Member.

William G. Raymond, Troy, N. Y., Consulting Engineer on new supply works, Troy, N. Y.; Carleton E. Davis, Upper Montclair, N. J., Engineer in charge of construction of new storage reservoir, Newark, N. J.

On motion of Mr. Fuller, the Secretary was directed to cast the ballot of the Association in favor of the applicants, which he did, and they were declared duly elected members of the Association.

The first item upon the program was a paper by H. W. Clark, Chemist of the Massachusetts State Board of Health, on "Investigations in Regard to Coloring Matter in Water and Methods of Removal." President Merrill announced with regret the receipt of a telegram from Mr. Clark announcing his inability to be present on account of illness, and called upon Mr. Desmond FitzGerald to address the meeting upon the subject-matter of Mr. Clark's paper. Mr. FitzGerald responded with an interesting contribution, and he was followed by Mr. R. S. Weston, — who spoke particularly of certain recent work in New Orleans, — Mr. C.-E. A. Winslow, and Mr. F.N. Connet, who described a portable device for color testing.

Mr. Caleb Mills Saville, Division Engineer, gave a description, illustrated by the stereopticon, of the work of the Metropolitan Water and Sewerage Board in the construction of reservoir and standpipe at Forbes Hill, Quincy, Mass.

The Committee on Apportionment of Charges for Private Fire Protection and the Means of Controlling the Supply Thereto was not ready to report, but a certain amount of progress was reported, and it appeared that the Committee is going into the matter with a good deal of thoroughness.

Adjourned.

Meeting of the Executive Committee.

715 Tremont Temple,
April 17, 1902.

The Executive Committee met at 10 A.M., President F. E. Merrill in the chair, and present, also, Messrs. L. M. Bancroft, C. W. Sherman, W. B. Sherman, H. O. Smith, R. J. Thomas, and Willard Kent, Secretary.

On motion of Mr. Thomas it was voted: That the President and Secretary be empowered to renew the lease from the Boston Society of Civil Engineers of the rooms in Tremont Temple, on terms at least as favorable as those of the present lease.

The choice of a place for the Annual Convention was the next business. The Secretary reported the result of the expression of opinion from members, as shown by the return postal cards, as follows: —

	Members.	*Associates.*	*Total.*
Boston,	110	15	125
Atlantic City,	84	6	90
Montreal,	70	14	84

After discussion, the Executive Committee voted unanimously in favor of holding the Convention at Boston.

It was voted: That the President, Secretary, Treasurer, and Advertising Agent, with Mr. Harold L. Bond (Associate), be a committee with full powers to make all arrangements for the Convention.

Adjourned.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XVI. September, 1902. No. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

HOW TO OBTAIN THE BEST RESULTS IN SMALL PUMPING STATIONS.

BY HARRY F. GIBBS, ENGINEER WATER WORKS PUMPING STATION, NATICK, MASS.

[*Presented February 12, 1902.*]

Mr. President and Gentlemen, — As you are all aware, there have been read before this Association a number of interesting papers on high-duty pumping engines, giving descriptions of the same, their cost, the duty obtained, etc. In New England every town of any size has its public water supply, and in a majority of cases the pumping engines are of the tandem compound condensing type, there being, so far as I know, but two water works supplying less than ten thousand inhabitants which have the fly-wheel type of pumping engine, — Abington-Rockland, and Andover, Mass.

We who are doomed to run the old type of engines that were the standard twenty years ago, — while we believe that the pumping engine of the future will be of some high-duty type, whatever the size of the town may be, and while we look with longing eyes at the nicely running fly-wheel engines in use in our cities, — in most cases can never enter the promised land. And, as we cannot alter present circumstances, let us see how we can make the best of existing conditions.

As there are many cases where superintendents are also engineers of their pumping plants, and in most such cases the plant has to be neglected more or less that they may give office and line work the necessary attention, I am constrained to prepare this paper, hoping it may prove useful in such cases. Also, where superintendents are

not obliged to handle the coal shovel, but are interested to know whether their pumping plants are giving the best results, I trust they may find in this paper some information that will help them in their conclusions.

Now, as the vital principle of the plant is contained in the boilers, let us begin there. We will assume that the boilers are of the horizontal return tubular type, of course proportioned to the work the engine has to do.

It has always been the custom, as far as I have observed, to proportion the grate surface according to the diameter of the boiler; that is to say, a boiler five feet in diameter will have a grate surface of twenty-five square feet. Whether the boiler is driven or not, I have always found these proportions too large, and in every case where I have reduced grate surface by bricking up the fire box on the sides, the duty of the pumps has been increased, and the temperature of the chimney gases decreased, as shown by the decreased temperature of the boiler room.

My smoke bonnet is painted with a paint mixed with oil, and it is not blistered and does not peel at all. The paint has been on about a year. My theory is that with a slow fire the gases are apt to ignite in the uptake instead of in the tubes.

In bricking up furnaces, care must be taken to fill in solidly behind the wall, so that no space shall be left through which air may be drawn up.

Next, are there any cracks in setting, iron fronts, on top, or in any fittings between uptake or chimney that will allow air to leak through? Test by taking a torch, with dampers open, and holding it near any such crack: if flame is drawn in, mark the place with chalk. Stop the cracks in brickwork with calcined plaster, using a putty knife. (Don't mix much plaster at a time, as it sets very quickly.) If there are air leaks on top of boiler where brickwork is built in against it, or over the back connection, lay down asbestos paper and cover it with fine sand. Calk spaces in ironwork with asbestos wicking and cover with putty. Be sure that brickwork over fire doors is tight, that the gases may not take a short cut to the chimney. You will be surprised at the results, if you had many cracks in the setting.

I will not touch on keeping boiler tubes clean, for of course you all do that.

Lack of air space in grates is a very bad disease. I have been in

the habit of splitting my grates and spacing them farther apart as a cure for this trouble. Now, that allows quite a lot of coke to fall through the grates. Well, on the last hour of my run I wet the contents of the ash pits and throw them into the furnaces, and from the refuse of a ton of coal I get fuel enough to run an hour. I have done this for twenty-one years, — and that means millions of gallons of water pumped with a waste product. Always keep ash-pit doors wide open; if you have a fireman and you find him closing the doors to check the fires, take them off all together. When fires are to be checked do it with the damper in the uptake or chimney; for checking at ash-pit doors is like trying to stop a runaway horse by dropping the reins, and putting brakes on the wheels. Put the bit in his mouth; or, in other words, use damper in chimney. You must get about twenty tons of air through your fires for every ton of coal you burn, and this will not be possible if ash-pit doors are closed. Also, the grate bars will last a great many years longer if they are kept comparatively cool.

Now as to feed water; the ordinary compound condensing pumping engine will give you a hot well temperature of about 100° F. Pumping from the hot well through heater will raise this temperature to 120° F. Now, if you will disconnect the exhaust of your air pump from the main heater, and have that exhaust go through another small heater (of course taking feed water through the same), this will bring the temperature of the feed water up to about 170° F. In plants that have no jacket pump a large amount of heat is being blown to waste through traps. I made some experiments with the steam loop, for the return of this water to the boilers; but having trouble in getting the loop high enough, I have adopted a device which pumps the jacket water into the feed pipe with the feed water increasing the temperature to such a point that the business end of a parlor match held against the pipe will melt and ignite. I don't know how hot the feed water is now, as my thermometer, which was graded up to 200°, blew up when it was immersed in the water. The water when drawn from the feed pipe has little jets of steam in it. The jacket condensation is a gallon every three minutes with a temperature of 315° F. In *Steam Engineering* of May, 1901, is a cut and description of the device, to which any one interested is referred. The cut is here reproduced as Fig. 1.

Feed steadily and from main pumps if possible, and thus save the steam, oil, and packing that it would take to run a feed pump.

If you have a damper regulator that won't keep the steam within a pound of a certain point, there must be something the matter with it, at least if it is of the more modern types. Causes for its not

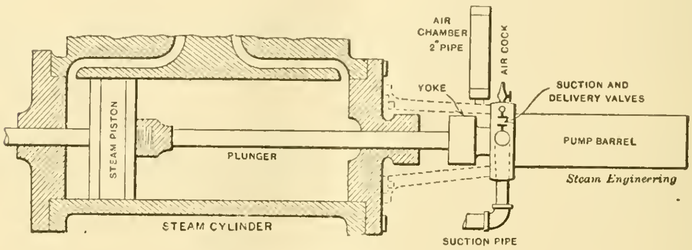


Fig. 1. — Jacket Pump.

working promptly may be, — the lever arm may touch somewhere, pressure pipe may be stopped up, or, if it is a water piston regulator, the valve may be either stuck or leaking.

As to the pumping engine itself, one thing of importance is to reduce engine friction as much as possible. One step in this direction is to have the piston rods packed in such a way as to reduce friction there as much as possible. A very good way is as follows: Take any round rubber-cored packing that is an easy fit for the stuffing box; cut rings as long as you can crowd into the box; put in a ring of packing, then take asbestos wicking and wind around rod twice and tie it once, then put in another ring of packing, and then more wicking, alternating until stuffing box is full; screw up the stuffing box hard and let it remain so until just before starting up, then slacken off the nuts as far as you can safely, and the steam and water getting in among the packing after a few minutes will pack the rod nicely. You will find that this way of packing will cause very little friction on the rods, and that they will take on a beautiful brown polish. If steam blows out around the gland, tie a piece of rag around that, and shove it home.

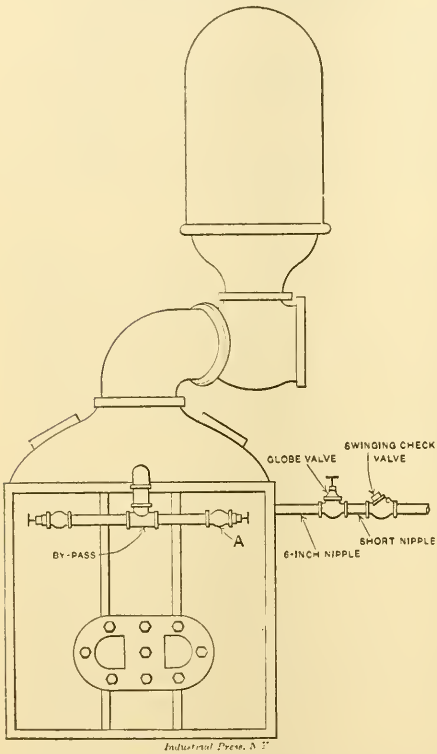
Next, are you sure that your high-pressure steam rings are not turned so that the split in them comes opposite the steam ports, causing a wasteful blow? Also center low-pressure pistons with your calipers, and be sure that the packing rings in that piston are set out in as true a circle as in you lies. Have you leaks in steam jackets that allow steam at boiler pressure to escape into low-pressure

steam chests or cylinders? I have known cases where the steam in jackets being left on all night would draw all the steam from the boilers, and condenser and air pump would be red hot in the morning. Such a leak will cause a heavy draft on the coal pile, and does no one any good. As to the locality of leaks, they are most liable to be found at bottom flanges of low-pressure steam chests. Our system of putting in gaskets is to use asbestos sheet packing, and after putting it into place wet it thoroughly so that flanges will bed themselves in it. At the place where the jacket holes come we put in extra pieces as large as fifty-cent pieces, and, of course, with holes in the center; these being also wet and stuck to the gasket reinforce the gasket at that place, and the joint will never leak. Cylinder heads are treated in the same way.

It is a good plan to go over all the bolts of the engine with a wrench occasionally, and improved vacuum, etc., will be the result. If your vacuum does n't hold steadily, search for leaks with a torch. Air leaks will usually be found, if at all, between exhaust pipe flanges on low-pressure cylinders and the air pump. I have one leak in a peculiar place; it is a blowhole in the iron at the bottom of a low-pressure piston-rod stuffing box; if the rod packing is not just right the leak affects the vacuum somewhat.

There is a difference in the way that engines must be run, for every engine seems to have an individuality of its own. For instance, one pump will run better with cross exhaust wide open, where perhaps in another the opposite will be the case. Find the point where the column of air in air chamber will give the best results. While upon this subject let me relate something that happened to me, and how we finally remedied the difficulty. One of our water takers, whose house is located on a dead end, was continually complaining of a water hammer on the service pipe. It was proposed to put an air chamber on the highest point of the service pipe, but that was objected to because it would be necessary to cut away a part of a shelf. The lady kept sending word to me about the hammer, and one day I noticed that the air chamber on the engine was nearly full of water, and the thought occurred to me that the trouble might be there; so I told the messenger that I would see what I could do to stop the trouble, and asked him to let me know the next forenoon if it still continued. That night I allowed the water to drain out of the pumps, and when starting anew the next day, of course, the air chamber was full of air. That stopped the ham-

mer on the service pipe, but I was to run up against more trouble. The people who are located on the force main began to complain of air in meters and service pipes, and so I had to invent some way to get air into the air chamber without any of it going into the mains, and without draining the pumps. The device is described and illustrated in *Steam Engineering* of November 15, 1901, from which the illustration, Fig. 2, is copied.



Device for Charging Air Chamber.

FIG. 2.

In regard to our plant, we have two engines, a Worthington cross compound condensing duplex pump, 18 by 36 by 14 by 24 inches, and a Blake tandem compound condensing pump, 12 by 24 by 14 by 18 inches, with independent air pump; also a boiler feed pump. We also have a 24-inch blower run by a Pelton water motor to obtain forced draft. We have two boilers 16 feet long, each having 72 tubes 3 inches in diameter; one boiler has lap joints double riveted; the other, butt joints with inside and outside covering plates, and is triple riveted. Our lift, including friction in force mains, is 215 feet. Our average duty is fifty-two million foot-pounds per hundred pounds of coal used, as per formula of uniform statistics.

This duty is obtained by using a fuel composed of one third bituminous coal from the Red Jacket mine, and two thirds anthracite screenings. The cost per long ton at the rate we paid for our coal last year is about two dollars and eighty-five cents. The term *duty* has very little meaning for the average man outside of those con-

cerned in water-works matters, and the gallons pumped per pound of coal is misleading, as an engine on a low lift giving low duty will show more gallons per pound of coal than a better one having a higher lift; so in my case I have thought best to find the total horse-power developed for the year, and by dividing that by the total coal find the number of pounds of coal used to develop one horse-power. That, it seems to me, is the plainest way to show to an unitiated inquirer which engine is doing the best.

Cylinder oil plays an important part in getting results from a steam jacketed engine, as one lubricator usually does all the work. Then again the M. E. P. in the high-pressure cylinder of a compound engine is so high that an oil that will not vaporize and do no good in the low-pressure cylinders is required. Therefore you will have to use considerable judgment in your selection of oil, and you will not always find that the highest priced oil is the best. Oil for your bearings should not cost over twenty cents per gallon. Grease is better, and cleaner when used in compression cups.

Be sure that the pipe that carries oil from the lubricator to the steam pipe is tapped half way into pipe, so that the oil will drop into the steam, and not run down on the inside of the pipe. Use some graphite on rods and in cylinders every day.

I know the Association will pardon me if I put in a word for the engineer. I think that universally the men who are in charge of pumping stations are conscientious and faithful, and I would ask superintendents to humor their little idiosyncrasies as regards the kind of oil, packing, etc., that they want. Personally I am fortunate in having a superintendent to whom I have only to express my preferences for material needed and it comes promptly.

Now, to sum up the whole matter, after everything about the plant is in repair, to obtain the best results is only a question of nursing; for, as I have said before, every plant has an individuality of its own, and you must study draft of chimney, in relation to the direction of wind, weight of atmosphere, etc., and govern your fires and fire accordingly. Adjust every part of your engine to give best results; find most economical pressure of steam and height to carry water in boilers and air chamber, and the most economical position of parts of engines in relation to their fellows, and you will be pleased with the results.

SMALL PUMPING ENGINES. — Topical Discussion.

[*February 12, 1902.*]

Mr. Wm. F. Codd.* At the Wannacomet Water Works, at Nantucket, for over twenty years there has been a steam pumping plant consisting of two horizontal tubular boilers, a Worthington pump, 18½ by 14 by 10 inches, and a Blake duplex pump, 8 by 6 by 10 inches, all in one building. This plant has been run successfully, without accident to require shutting down and stopping the water supply; but it was not considered safe to have the water supply of the town longer dependent on one plant, which might be crippled by fire or other accident. It was therefore decided to build an entirely separate and distinct pumping plant, principally as a reserve.

Machinery which could be laid up without much deterioration, and which could be easily and quickly put in operation, was required; and the outcome was a new pumping station, built on the opposite side of the pond from the steam station, and equipped with a Fairbanks-Morse gasolene engine of sixteen horse-power, connected by a friction clutch to a Deming triplex single-acting power pump, 8½ by 8 inches, of a nominal capacity of three hundred gallons per minute (see Plate I).

After this plant was installed, the ease and certainty of its operation, its freedom from the dust, dirt, and labor incident to a coal plant, and its generally satisfactory condition, induced us to use it in preference to the steam plant. From April to December, 1901, it pumped nearly all the water used in town.

In the winter the steam plant is used, that station being kept warm, thus protecting the pipes from freezing, etc.

Our water tank being of only fifty thousand gallons capacity, and our consumption varying from sixty thousand gallons daily in winter to three hundred thousand in summer, frequent and short runs and considerable night pumping are required, making it rather expensive, both for fuel and for engineers' services. If we had a larger stand pipe, the services of one engineer would be enough.

The gasolene plant runs as smoothly and nicely as could be wished,

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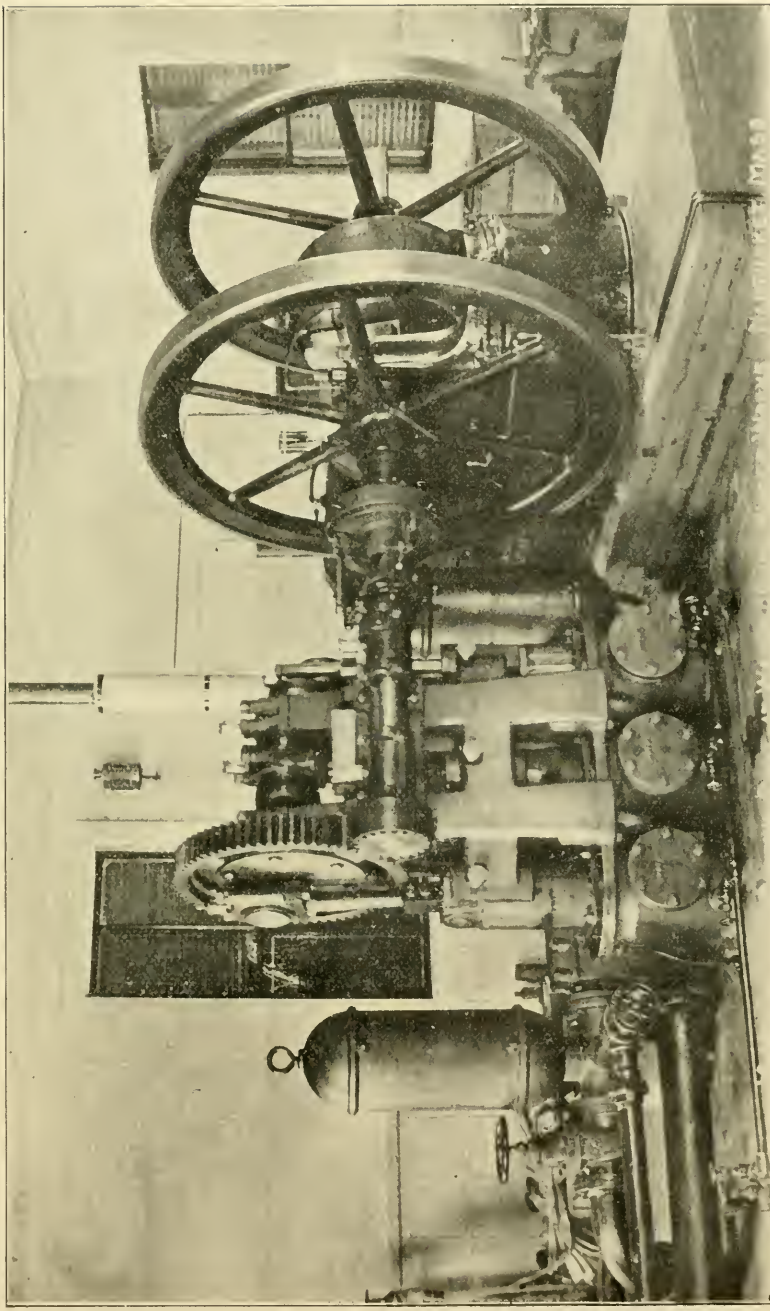
*Superintendent Wannacomet Water Company, Nantucket, Mass.

PLATE I.



SIXTEEN HORSE-POWER GASOLENE PUMPING PLANT AT NANTUCKET, MASS.

yet it requires intelligent attention at intervals, to see that oil cups are filled and delivering proper amounts of oil, and that all parts are properly adjusted. Such a plant should not be left to the care of any one not acquainted with machinery, with the idea that it will run forever without getting out of adjustment.

After a run is completed, the oil cups are refilled; the engine is wiped off; a new match for starting is prepared and put in place, and the engine is ready for another run. It then requires not over three minutes from time of entering the building, to start the engine and throw in the pump, and the machinery is going at its full capacity.

We buy gasolene in barrels, shipped to us by railroad and sailing vessel, and store it in a tank made of an old, horizontal boiler we had, of about one thousand gallons capacity. It flows from the boiler-tank, by gravity, to the fifty-gallon supply tank placed in the ground just outside the building, from which it is pumped to the engine by a small pump on the side of the engine frame, worked from the crank shaft.

During the eight months the gasolene plant was used, in 1901, the

Time of running was	1 811 hours.
Duration of continuous runs	from 1 to 15 hours.
Quantity of water pumped	33 343 700 gallons.
Average dynamic head of water, including suction lift	108 feet.
Gasolene used	3 207 gallons.
Cylinder oil	44.5 gallons.
Grease	55 pounds.
Waste	115 pounds.
H. P. required to raise water	8.34
H. P. required to run pump	4.17
H. P. developed by engine	12.51
Water raised 108 feet by 1 gallon gasolene	10 400 gallons.
Water raised 100 feet by 1 gallon gasolene	11 230 gallons.
Gasolene consumed per hour	$\frac{3207}{1811}$ = 1.77 gallons.
Gasolene consumed per H. P. hour	$\frac{1.77}{12.51}$ = 0.141 gallons.

Duty, 9 364 932 ft. lbs. per gallon of gasolene =
1 440 759 ft. lbs. per pound of gasolene.

Cost of gasolene, at water works	15 cts. per gallon.
Total cost of gasolene	$481.00
Total cost of oil, grease, waste, and battery renewals	$41.42
Total running expense	$522.42

$\frac{522}{33\frac{1}{3}}$ = $15.60 per million gallons of water 108 feet high.
$14.44 per million gallons of water 100 feet high.

Repairs to engine and pump	nothing.
Cost of machinery set up was about	$2 000

Compared with steam plant, used in 1900, where —

Quantity of water pumped was........................32 500 000 gallons.
Quantity of coal used...........................241 265 lbs. = 120 tons.
Cost of coal at water works about ....$4.75 per ton.
To pump 1 000 000 gallons water required................624 lbs. gasolene.
To pump 1 000 000 gallons water required.................. 7 423 lbs. coal.
(Proportion about 1 to 12 by weight.)
Cost of 120 tons of coal $570
Oil, waste and supplies about 50

Total cost $620

Equal to $19.07 per million gallons 108 feet high.
$17.66 per million gallons 100 feet high.

Mr. D. N. Tower.* We have had in operation for the past four years a kerosene oil plant with a Hornsby-Akroid engine of about thirteen horse-power. This has been run from November to March in each year, averaging about one hundred and eighty days, and pumping on an average one hundred and twenty thousand gallons a day. The man starts it in the morning at about seven o'clock, and it is discretionary with him when to shut down, but it is usually in operation from twelve to fourteen hours a day. Last year the average daily consumption of oil was sixteen and nine-tenths gallons to pump one hundred and twenty thousand gallons of water; that is, about one gallon of oil to raise seven thousand gallons of water one hundred and sixty feet. It has worked very satisfactorily. The first year we had some little expense for repairs, as we did not fully understand the machine, but for the last three years we have had no trouble at all with it. There has been really no expense for attendance, because the man who starts the engine in the morning does so when he goes to his day's work, and I pay him $2.25 a day, while I can charge $3 a day for his services most of the time.

* Superintendent of Water Works, Cohasset, Mass.

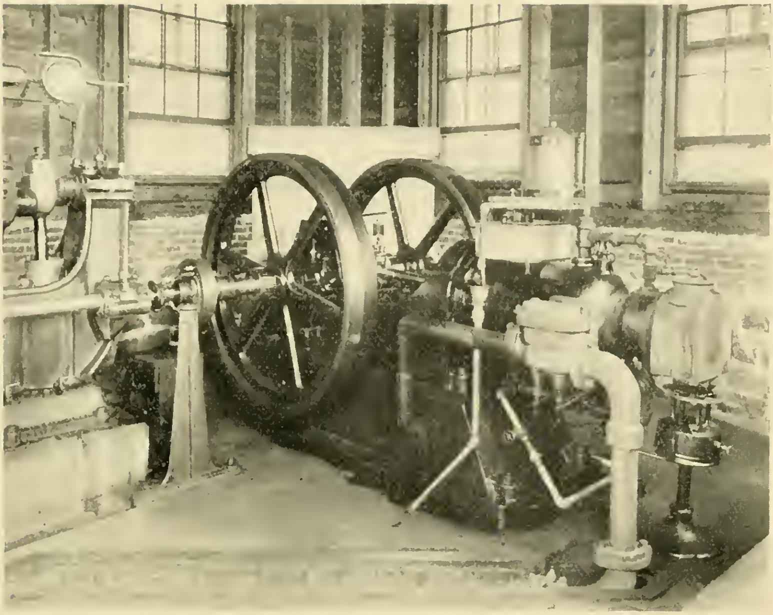


FIG. 1.—KEROSENE ENGINE, COHASSET WATER WORKS.

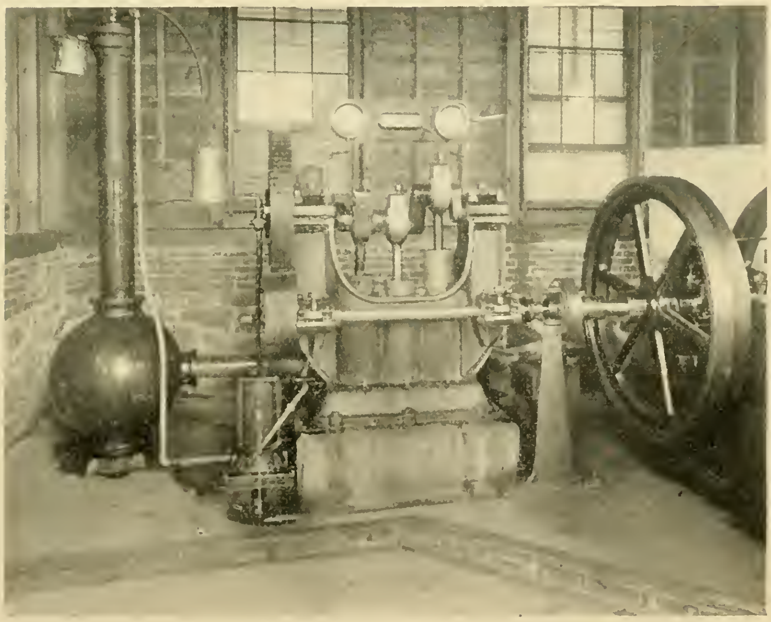


FIG. 2.—PUMP GEARED TO KEROSENE ENGINE.

THE CONSTRUCTION OF A RESERVOIR AND STAND-PIPE ON FORBES HILL, QUINCY, MASS.

BY C. M. SAVILLE.*

Mr. President and Gentlemen, — At the request of your secretary I have pleasure in presenting to you to-day a description and some details of construction of a small storage reservoir and a standpipe recently constructed for the Metropolitan Water and Sewerage Board on Forbes Hill, in Quincy. Mr. F. P. Stearns is chief engineer of this board, and the work of which I shall speak was done under the supervision of the Distribution Department, of which Mr. Dexter Brackett is engineer.

The object of the work was to furnish storage and protection to the southern part of the water district in case of accident to pumps or water mains; to provide for sudden and unusual drafts, and to act as an equalizer at this end of the system. With these ends in view, Forbes Hill was selected as offering the most favorable location. This hill is situated in Quincy, about one mile from both the Wollaston Heights and East Milton stations, on the Plymouth Division, New York, New Haven & Hartford Railroad. It is what is known to geologists as a drumlin, a hill oval in shape and composed of unstratified glacial drift or "hard pan." The summit of the hill was about one hundred and ninety feet above low water in Boston Harbor, bare of trees, and afforded a magnificent view of the surrounding country.

A map of the Metropolitan Water District showing the pipe lines and the position of Forbes Hill Reservoir, in Quincy, is shown in Fig. 1.

In designing the work it was decided that the reservoir should have a capacity of about five million gallons, and be so placed on the hill that the amount of material excavated should approximately equal that necessary for embankment. The standpipe was designed to hold about three hundred thousand gallons, with its overflow at about the elevation of Fisher Hill Reservoir, Brookline, into

* Division Engineer, Distribution Department, Metropolitan Water Works.

which the pumps at Chestnut Hill also deliver water for the high-service supply of Boston.

From the indications of a test pit dug at the point of greatest excavation and to the depth of the bottom of the proposed reservoir, the material underlying the soil was estimated to be very hard and compact, containing many stones and small bowlders and sufficient

FIG. I.

clay to make an excellent embankment, which would be impervious to water without the use of a core wall.

As designed and built, the reservoir is oblong, with its long axis running approximately east and west. Its bottom is 280 × 100 feet in size, and slopes slightly toward a center drain, which also pitches to a sump in the west end. The slope of the surface of the banks on the water side is one foot vertical on one and three-quarters feet horizontal. The corners are rounded like the surface of an inverted

right cone, having the apex at the surface of the concrete at the bottom. The top of the bank is about seventeen feet wide, and the outer slope is one foot vertical on two feet horizontal. The inner slope and bottom are covered with concrete, extending, on the slope, about two feet vertically above high water. On top of the bank is a granolithic walk, six feet wide, encircling the reservoir. On either side of the walk and on the outer slopes the bank is laid down to grass. In order to dispose of material of a loamy nature, which it was thought unwise to use in the main banks, a berm twenty feet wide was built along the entire northerly side, where the built-up bank was highest. The gate chamber is located at the west end, partly in excavation and partly in embankment. Flights of granite steps on either side lead to the walk about the reservoir.

Nearly opposite the gate chamber is the steel standpipe, thirty feet in diameter and sixty-four feet four inches high, resting on a heavy concrete foundation, in which is a vault containing the gates for controlling the water in the standpipe. The standpipe is enclosed in a granite masonry tower, the roof of which, reached by a circular iron stairway, can be used as an observatory.

All of the above-described work is completed except the tower, which is now under construction. The plan and typical sections of the reservoir are shown in Fig. 2.

RESERVOIR.

On June 26, 1900, bids for building the reservoir and standpipe foundation were received, based on an estimate of quantities which, together with the bids, is given in Table No. 1.

The contract was awarded, July 7, to Messrs. Beckwith & Quackenbush, of Mohawk and Herkimer, N. Y. On July 16, the contractors began to bring materials and tools upon the ground and commenced erecting an office and cement shed. Almost the first thing done was to set up a single-drum hoisting engine and boiler, which by means of a wire cable helped haul heavy loads up the hill. The nearest public street was nine hundred feet away from the work. From this the way to the top of the hill rose with an almost uniform slope of ten feet per one hundred, partly over a private street and partly over the open hillside.

Excavation and Embankment. — The reservoir site was first stripped of loam to a depth of about two and a quarter feet. A sufficient quantity of this was placed in spoil banks, from which it

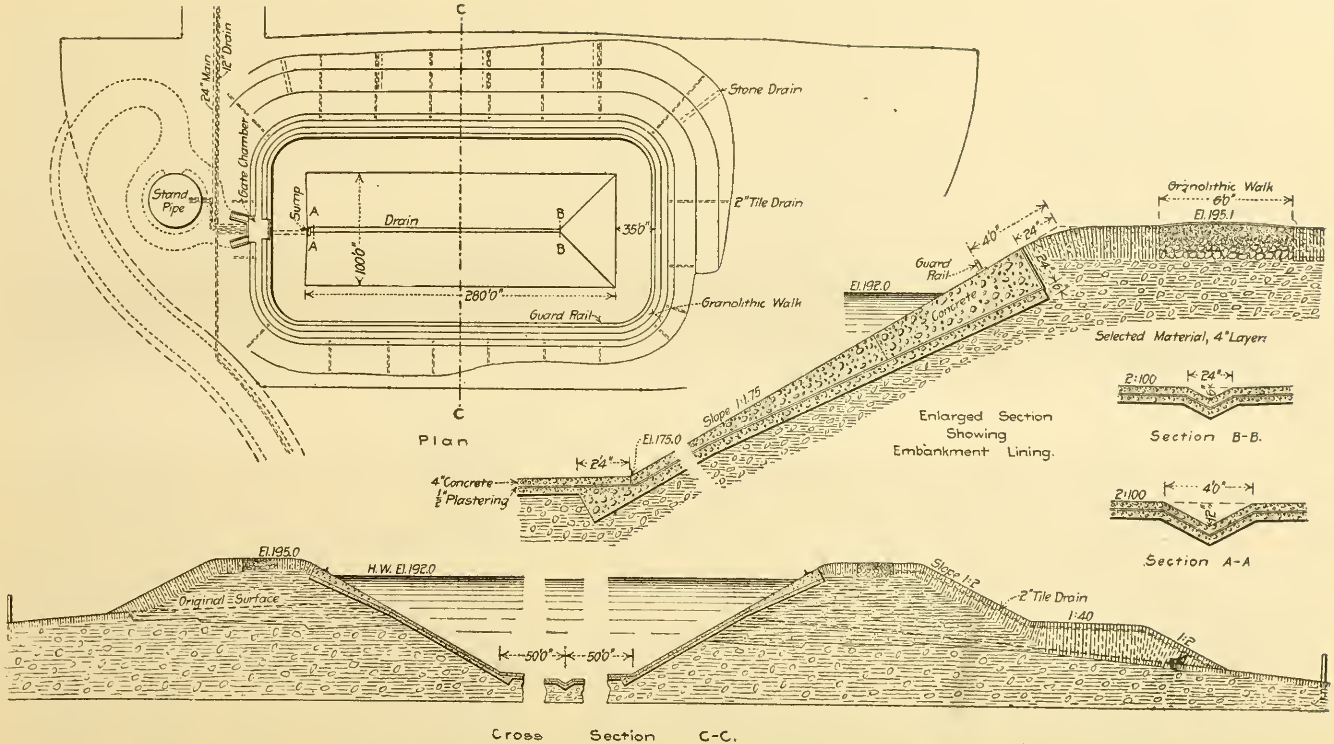


FIG. 2. PLAN OF RESERVOIR AND-STANDPIPE AND SECTIONS OF RESERVOIR.

Table No. 1.

METROPOLITAN WATER WORKS — DISTRIBUTION DEPARTMENT.

RESERVOIR AND FOUNDATION FOR STANDPIPE, FORBES HILL, QUINCY.

CONTRACT NO. 192. CANVASS OF BIDS. RECEIVED JUNE 26, 1900.

	ITEMS AND QUANTITIES.		BIDDERS AND PRICES.												
			Beckwith & Quackenbush, Mohawk, N. Y.	Fallon Bros., Quincy, Mass.	Thomas & Connor, Middleboro, Mass.	Bruno, Salomone & Petitti, Boston, Mass.	Ferullo & Co., Boston, Mass.	Donato Cuozzo, Brooklyn, N. Y.	Cenedella Bros., Milford, Mass.	Bell & Co., Boston, Mass.	Joseph Ross, Boston, Mass.	Warren Bros. Co., Bosto , Mass.	The C. H. Eglee Co., Boston, Mass.	Jesse Moulton, Boston, Mass.	John Cashman, Quincy, Mass.
1	Earth excavation	26 800 cu. yds.	$ 0.38	$ 0.47	$ 0 36	$ 0.33½	$ 0.50	$ 0.40	$ 0.35	$ 0.50	$ 0.48	$ 0.60	$ 0.48	$ 0.48	$ 0.65
2	Rock excavation	50 ,,	2.50	2.00	1.25	2.90	2.00	2.00	2.25	5.00	4.00	2.50	2.00	3.00	2.00
3	Portland cement concrete masonry (Class A)	270 ,,	8.00	6.15	7.50	7.50	7.00	7.50	7.65	10.50	10.75	10.40	10.75	9.50	8.75
4	Portland cement concrete masonry (Class B)	320 ,,	6.00	5.25	5.60	6.75	6.00	6.75	6.40	7.00	8.50	6.60	8.50	7.00	7.00
5	Am. natural cement concrete masonry (Class C)	420 ,,	5.25	4.20	4.75	5.50	5.00	5.00	6.25	5.50	5.95	5.25	5.90	5.75	6.00
6	Portland cement concrete masonry (Class D)	630 ,,	6.00	5.25	6.00	7.00	6.00	6.75	7.00	6.75	7.50	6.90	7.50	6.25	7.50
7	Portland cement concrete masonry (Class E)	1 300 ,,	7.00	6.40	7.65	8.00	7.00	7.75	8.75	8.50	8.45	9.00	10.25	9.50	9.60
8	Plastering	7 100 sq. yds.	.25	.40	.48	.45	.40	.40	.65	.35	.48	.35	.50	1.00	.35
9	Granolithic walk	700 ,,	1.89	2.00	1.87	2.16	2.00	1.75	3.35	1.90	2.30	2.16	2.50	2.25	2.16
10	Granite ashlar masonry	8 cu. yds.	40.00	25.00	14.00	20.00	10.00	25.00	20.00	18.00	40.00	25.00	20.00	20.00	20.00
11	Granite dimension stone masonry	10 ,,	60.00	60.00	30 00	25.00	20.00	40.00	35.00	30.00	65.00	42.00	35.00	60.00	50.00
12	Brick masonry	5 ,,	18.00	14.00	15 00	15.00	10.00	12.00	20.00	15.00	25.00	16.00	12.00	20.00	25.00
13	Laying 24-inch cast-iron pipe	190 lin. ft.	.30	2.50	1.25	1.25	.40	1.50	1.50	1.00	.40	1.00	1.50	1.25	2.50
14	Laying 30-inch cast-iron pipe	30 ,,	.40	2.40	1.75	1.50	.50	1.75	1.50	2.00	.50	1.50	2.00	1.50	3.00
15	Making connections of supply and drain pipes in and between the gate chamber and the standpipe		120.00	250.00	570.00	250.00	75.00	250.00	250.00	250.00	300.00	250.00	200.00	200.00	200.00
16	Furnishing and laying 12-inch vitrified pipe drain	150 lin. ft.	.50	.60	.40	.50	.35	.60	.50	1.00	.60	.60	.50	.80	1.00
17	Woodwork and covering for gate chamber		480.00	375.00	300.00	500.00	300.00	600.00	550.00	250.00	425.00	315.00	125.00	350.00	500.00
18	Driveways	700 sq. yds.	.35	.40	.75	.25	.50	.50	1.00	.72½	1.40	.70	.65	1.00	.75
19	Gravel walks	300 ,,	.50	.75	.75	.75	.20	.75	2.10	1.00	1.03	.60	.90	1.00	.75
20	Seeding	1 acre.	15.00	50.00	28.00	25.00	50.00	75.00	225.00	119.00	90.00	80.00	20.00	100.00	50.00
	Totals		$34 736.00	$36 355.00	$36 449.50	$37 152.50	$37 838.50	$38 085.	$42 346.00	$42 498.00	$45 293.50	$45 714.00	$46 474.50	$48 109.00	$48 844.50

Awarded to BECKWITH & QUACKENBUSH.

was later re-excavated and placed on the outer slopes of the banks. Five of these spoil banks were built, located with especial reference to rehandling the loam as cheaply as possible. Two of them were for the blackest and best of the loam, and the others for that of a poorer quality. The remainder of the loamy material was placed in the berm with one handling. The average cost of stripping the loam is shown in Table No. 2.

After the soil was removed the material generally was found to be very compact and hard to excavate, and any water from rain or hose would stand in puddles on the surface until it was evaporated rather than absorbed. When the excavation for the gate chamber and pipe trench was made, the sides were carried down vertically for fifteen or twenty feet without any bracing whatever, and in the case of the gate chamber these walls were even battered back into the bank at the rate of 1 to 12. Twice, before concrete was put in, there was a depth of from ten to twelve feet of water in the chamber for one or two days, which drained from rain falling in the reservoir. When, however, it was pumped out, the sides of the bank seemed to have suffered no damage.

The material excavated varied somewhat, some portions being a little more gravelly than others. As a rule, however, four horses on a pavement plow, with continual cross plowing to break down the material between the furrows, was necessary.

The contractor tried blasting to loosen the material. The holes at first were drilled by hand, two men on a churn drill making about ten linear feet of holes per day. Later a steam drill was used, making about thirty feet per day. These holes were located at the corners of ten-foot squares. When the powder was exploded the ground was considerably shaken and loosened. Unfortunately, however, there came a rain storm that same night which caused the loosened material to settle back into place, apparently as solidly as ever. Later, however, it was found that this portion of the work was much more easily excavated, and the contractor was very sorry that the blasting had not been continued. The contractor himself was away at this time, and his foreman, anxious to make a good record and discouraged by the seeming mishap to the loosened material, abandoned blasting, with which for this purpose he was unfamiliar, and returned to plowing.

In order to soften the material somewhat, one or two men were employed each night to thoroughly wet the surface to be plowed the

Table No. 2.

EARTHWORK — EXCAVATION AND EMBANKMENT.

COST OF WORK.

Total quantities moved . . . . 32 334 cu. yds.
Cost $13 097.39
Cost per cu. yd. 405

Comprising the following: —

GROUP I. — Soil Excavation.
To spoil banks and berm.
From spoil bank to reservoir bank.
Quantity moved . . . . 13 868 cu. yds.
Cost $3 243.35
Cost per cu. yd. 234

GROUP II. — Material in Reservoir Bank and Backfilling Trench.
Quantity moved . . . . 18 466 cu. yds.
Cost $9 854.04
Cost per cu. yd. 534

	Nature of Work.	Cubic Yards.	Cost in Detail. Loosening.	Scraping.	Loading Carts.	Teaming.	Rolling Banks.	Unloading and Spreading.	Excavation from Trenches.	Backfilling Trenches.	Surplus from Trenches to Reservoir Bk.	Total Cost per Cubic Yard.	Remarks.
GROUP I.													
a.	Stripping — To spoil banks and berm	8 722	$0.034	$0.140	. . .	. . .	. . .	$0.006	. . .	. . .	. . .	$0.180	Loosened by plows; excavated and transported by scrapers.
b.	Yellow loam — Spoil banks to reservoir bank	3 601	.054	.223	. . .	. . .	. . .	.029	. . .	. . .	. . .	.306	Loosened by plows; excavated and transported by scrapers.
c.	Black loam — Spoil banks to reservoir bank	1 545	.048	.228	. . .	. . .	. . .	.096	. . .	. . .	. . .	.372	Loosened by plows; excavated and transported by scrapers.
GROUP II.													
a.	Major part of hard-pan exc. .	15 786	.109	.222	. . .	. . .	$0.039	.077	. . .	. . .	. . .	.447	Loosened by plows; excavated and transported by scrapers.
b.	Trimming and grading slopes and bottom	1 500	.562	. . .	$0.306	$0.228	.044	.063	. . .	. . .	. . .	1.203	Loosened and excavated by hand; transported by carts.
c.	Exc. gate chamber, standpipe foundation, pipe trench . .	{ 750	. . .	. . .	. . .	. . .	. . .	. . .	$0.605	$0.174	. . .	.779	Loosened, excavated, and backfilled by hand; surplus transported by scrapers.
		{ 430	. . .	. . .	. . .	. . .	. . .	. . .	.605	. . .	$0.339	.944	

next day. This scheme succeeded admirably if care was exercised not to get the ground too wet and if it was possible to excavate the damp material before it dried and became hard again.

In starting the embankments, the ground was first thoroughly cleaned of loamy material to a depth of at least two and one-half feet, for a distance inward from the outer toe of the slope equal to about one third the width of the bank. At this point a quick drop of about one foot was made and excavation continued at this depth for about another third of the width, when a second drop of about one foot was made and the excavation carried at such a depth that at the inner edge of the bank it would be about five feet below the original surface. This method stripped from under the banks all soil, and practically removed from the inner third all material that could have been disintegrated by frost. In stepping down no attempt was made to get the sharp corners often shown on plans, as it was thought that the material could be packed more solidly against a sloping surface than in the apex of a sharp re-entrant angle.

The bank was started in the lowest places, the undisturbed material being well wet and thoroughly rolled before placing other material upon it. The contractor had a number of methods of work somewhat unusual about Boston, but common enough in some other parts of the country. Some of the methods, under proper circumstances, deserve more extended use. The work of excavation is shown in Plate I, Fig. 1.

All the excavation, except a few hundred cubic yards in the bottom of the reservoir, was done either with wheel or drag scrapers. The wheel scrapers resemble immense square-pointed coal scoops, and are drawn by two horses. They are so balanced on two iron wheels that, by means of handles behind, the cutting edge can be lowered, and when the scraper is pulled ahead the material is pushed up into the bowl of the scraper. When full, by bearing down on the handles, the cutting edge is raised, and an iron hook automatically catches and holds the bowl in place until the dumping ground is reached; the hook being then released, the cutting edge strikes the ground, and the load is dumped by the movement of the horses which overturns the scraper.

The drag scrapers are similar in shape, but without the wheels.

The ordinary gang on the work in the hard pan was made up of a four-horse hitch on a pavement plow, one man driving and one or

FIG. 1.—EXCAVATION AND BANK BUILDING.

FIG. 2.—BUILDING RESERVOIR BANKS.

two men on the handles; four or six scrapers, depending on the length of the haul; an extra pair of horses, called a "snap team," which helped load each scraper; a man to hold the scraper handles while loading; and, if the material was very hard to excavate, two or three extra men to complete the scraper load with shovels. The haul for the wheel scrapers was not over two hundred and fifty or three hundred feet, and for the drag scrapers about one fourth of this distance.

Theoretically, the wheel scrapers carried about three fourths of a cubic yard and the drag scrapers about one half this quantity. Under favorable conditions in a soft or sandy soil they would undoubtedly take this amount; but in the material here excavated not more than one half as much was excavated per load. At first sight this seems a small amount; but if properly regulated for distance and number of scrapers to a gang, an immense amount of material can be moved in a short time, and at a small expense. When the work was well under way in the hard-pan excavation, under favorable conditions of haul, each team averaged thirty-five cubic yards per day, and under unfavorable conditions thirty cubic yards, making from eight to ten trips per hour.

Excavation by scraping is hard on both horses and driver, as the team is continually in motion.

Even under the adverse condition of the material here excavated, the use of scrapers was found to be much more economical than cart work while the banks were low and the haul short. This was demonstrated on the work as follows: —

One forenoon two of the scrapers were out of commission for repairs, and two others were taken off, leaving one gang of four scrapers at work. Single tipcarts were substituted for the other scraper gang. A careful record was kept of the work done by these two methods, which proceeded side by side and under identical conditions. Without including charges for foreman and for loosening the material, which were the same under both methods, it was found that four scrapers, one snap team, and four men beside the drivers moved to the banks one hundred cubic yards of hard pan in five hours at a cost of fifteen and one-half cents per cubic yard; while six carts with fourteen men beside the drivers moved seventy-five cubic yards in the same time at a cost of twenty-four cents per cubic yard. The quantities moved during this time were more than were generally averaged, as the gangs were working against each

other; nevertheless, the proportionate relation of the methods under similar conditions of haul and material holds good.

Three rollers, each weighing about four thousand pounds and drawn by two horses, were used on the banks. These rollers were composed of gangs of separate cast-iron wheels, the alternate ones being of larger diameter than the others. Two of these rollers were four feet wide and the other about six feet wide. The method of building and rolling the banks is shown in Fig. 2 of Plate I.

In order to provide water for wetting the bank and later for the concrete work, a one and one-half inch wrought-iron pipe was laid entirely around the reservoir, a distance of about fifteen hundred feet. This pipe had hose connections about fifty feet apart, controlled by small valves. The pipe was connected at both ends with the twenty-four inch main, but when a number of streams were wanted at the same time and through long lengths of hose, considerable trouble was found in getting a sufficient supply in those portions farthest from the main. Three-quarter inch hose was used, and a nozzle throwing a fan-shaped spray gave excellent results. By this means water could be applied where needed, and places already sufficiently wet could be avoided.

The banks were put down in layers four inches thick before rolling. Parallel with the axis of the bank the layers were kept approximately level; crosswise they were given a slope toward the reservoir of about 1 in 50. Beginning at about three feet from the top, this slope was gradually changed to a very slight pitch outward, to keep water falling on the top of the bank from washing the inner slopes when ready for concrete.

Just before placing the dry material, the place where it was to be dumped was thoroughly soaked, then the load was dumped and partially leveled by the scraper edge. Laborers then spread the layer evenly, picking out stones larger than about three inches in their greatest diameter, especially those which would project above the layer when rolled. As great care as possible was also taken that a number of smaller stones should not lie together, but that they should be separated by the hard pan. When a sufficient length of bank had been spread, the roller was run over it three or four times to break up any lumps, consolidate the material, and drive up water from the under layer. After this it was sprinkled and rolled until the whole surface had a fresh, bright appearance and the wheels of the roller left only a faint impression upon it. Sufficient water was

constantly applied under this second rolling to make the material plastic, but not liable to peel under rolling. After a little experience the proper amount of water could be determined by inspection, but no rule could be followed, as the material varied so in the amount of clay it contained.

If the bank was too wet, either from sprinkling or from rain, it would rise in a wave in front of the roller, and work had to be stopped at that point until the bank had dried. On this account some difficulty was found in keeping laborers. Just after a rainy day or two, even if the weather were fair and clear, excavation could not be carried on, as the banks were not sufficiently dry to be worked on, and the material was too wet to be properly laid down. Usually the banks were ready for work long before the material could be excavated.

As a rule, the banks were kept level as stated. At the southwest corner, however, the bank was left low for a time on account of the roadway for bringing the last of the material from the bottom and carrying in materials for concrete work. On the easterly end, during the latter part of the work, the bank was built to grade as soon as possible, in order that concrete work might start. The layers of the embankment in these places were stepped back at the rate of about ten feet for each four-inch layer.

In order that that portion of each layer near the inner slope might be rolled as thoroughly as others, the bank here was built with an extra width of about a foot, and this excess portion trimmed off just before the concrete lining was laid. The trimming of these slopes, the excavation to grade in the bottom, and the taking out of the roadway were the most expensive parts of this work.

An idea of the comparative cost of this work is to be had from Table No. 2. The slopes were plowed twice, and the material cast down the bank to the bottom. At first drag scrapers were tried, but were soon abandoned for pick and shovel, as the scrapers dug so deeply and unevenly into the bank.

Carts were used for transporting materials excavated on this portion of the work. They were of a pattern seldom used here, being of the self-dumping variety, holding from one and one-half to two cubic yards, and drawn by two horses. Being somewhat longer than the usual two-horse dump cart, they allowed a larger gang of men to work around them while being loaded. When the dump was reached, without stopping his horses, the driver with one hand re-

leased a pawl, which allowed the two leaves forming the bottom to swing downward, dumping the load. On the way back, by means of a lever and chain working over a sprocket wheel, he would draw up the bottom, ready for the next load.

The method employed with these carts was to have two of them for one pair of horses, and while one cart was on its way to unload the other was being filled. On his return the driver would change his horses to the now-loaded cart, leaving the empty one to be filled. Beside utilizing the horses, which are the most expensive item in team work, to their utmost capacity, the laborers also were urged along by the fact that the cart must be loaded by the time the horses returned. Beside being easily unloaded, materials could be landed by these carts in places where ordinary carts could not be drawn and dumped.

When November of 1900 came, finding the embankments and excavation still far from completion, it was decided to protect the banks during the winter by filling the reservoir with water. The banks were built to elevation 189, six feet below the top of the finished bank and three feet below the top of the hard pan. A belt of riprap (see Plate II, Fig. 1) about five feet wide and six to eight inches thick was laid around the top of the bank to protect it from wave action, and water was admitted very slowly up to about the middle of the riprap belt. Two weeks were taken to raise the water level ten feet, in order that the banks might not be too suddenly disturbed and slide. Frequent levels were taken on the water surface during the winter, and the entire hillside was carefully examined for any unusual flow of water. During this time the surface lowered very little, not more than could be ascribed to evaporation from water in such a high and exposed place.

In the spring the rains filled the reservoir so rapidly that it was necessary to lower the surface eight or ten inches very quickly. The outlet into which the reservoir drain discharged not being of sufficient size to care for so large a quantity of water in so short a time at this season, when the natural drainage was itself very large, another temporary outlet had been planned and was in process of construction. This was not quite in condition for use, and as there seemed a possibility, at least, that the water might overtop the banks, two wrought-iron pipe siphons, one four inches and the other one and one-half inches, were set up and used for a day or two until the temporary outlet was ready. Previous to setting up the

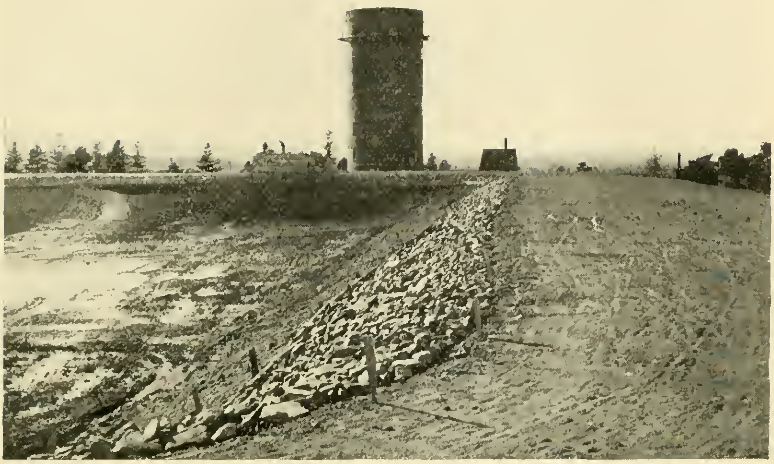


FIG. 1. — CONDITION OF WORK AS LEFT FOR WINTER OF 1900.

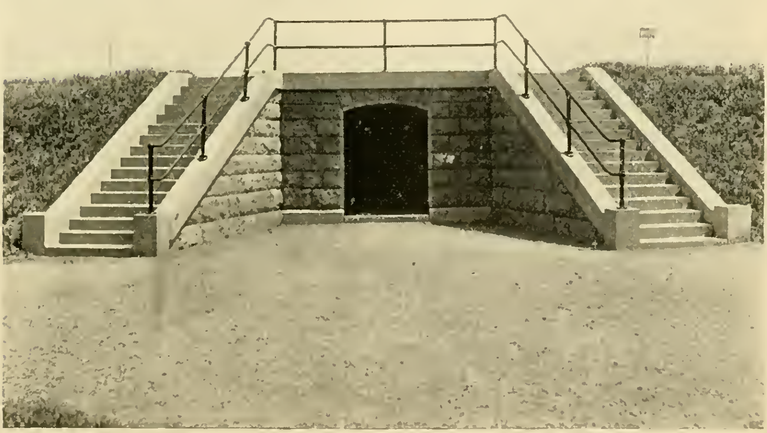


FIG. 2. — ENTRANCE TO GATE CHAMBER.

pipes, a very successful siphon was made with the suction hose from an ordinary diaphragm pump.

After this the water was withdrawn very slowly and the banks carefully watched for cracks and slides. A slight slide of a few cubic feet occurred while the water was being lowered at the rate of three quarters of an inch per hour. The rate was at once reduced one third, and no further trouble occurred.

Before leaving the work in the fall, levels were taken over the embankments, and in the spring were again taken in the same places, but no settlement was apparent.

After the hard-pan portion of the banks was finished and the concrete work nearly done, yellow and black loam was taken from the spoil banks and put on the outer slopes. Here a feature of the scraper work was developed that should be taken into account in similar work. It had been expected that there was plenty to put two feet of yellow and one foot of black loam on the banks and still have a surplus remaining.

After a short time it was seen that the yellow loam surplus was not to be as great as had been expected, and directions were given to cut down the depth of the loam layer six inches in order to have an even layer over the whole surface. In looking about for the cause of this reduction, it was found that the amounts scattered by the scrapers in taking the long haul from the loam piles to the banks fully accounted for it. After the loam piles were all removed, except one which still remains at the west end for future use, the ground all about the reservoir was plowed up, harrowed, and sowed to grass. After the banks were covered with soil they too were sowed with grass seed and winter rye, scattered over with fertilizer, and rolled.

It was estimated that about 1 043 cubic yards of stone, too large to be rolled into the banks, were picked out from the excavated material. The greater part of this stone was removed by a gang of men and a cart following the plows. A considerable portion, however, was thrown out from the layers as spread on the bank. This stone was thrown over the outside of the slope. Below the berm it was allowed to be buried. Above the berm it was removed to the stone piles. To provide drainage for any water which might collect in this stone layer, cross ditches filled with stone were dug through the berm from fifty to seventy-five feet apart.

Most of the stone was placed in piles, and afterward either

crushed and used in the concrete or placed in the foundations of the walk and driveway. Table No. 3 shows the quantities of material excavated during this work and their final disposition. Table No. 2 shows the cost of the excavation in detail.

Table No. 3.

QUANTITIES — EXCAVATION AND EMBANKMENT.

Total quantity of material moved			32 334 cu. yds.
1st Handling.			
Black loam to spoil banks		2 414 cu. yds.	
Yellow loam to spoil banks		3 808 ,,	
Yellow loam to berm		2 500 ,,	
2d Handling.			
Black loam spoil banks to reservoir bank		1 545 ,,	
Yellow loam spoil banks to reservoir bank		3 601 ,,	
2d Handling.			
Material used in main portion of (trimming inside slope) reservoir bank		1 000 ,,	14 868 ,,
			17 466 cu. yds.
* Stone from Excavation.			
Used for concrete	1 495 x 54% solid	807 cu. yds.	
Used for foundation of walk	232 x 50% ,,	116 ,,	
Used for foundation of drive	140 x 50% ,,	70 ,,	
Spoiled in berm	100 x 50% ,,	50 ,,	1 043 ,,
Material used in main portion of reservoir bank			16 423 cu. yds.
Volume in main portion of reservoir bank			15 474 ,,
Shrinkage in material used — Quantity			949 cu. yds.
— Percentage			6%
Material excavated for use in main portion of reservoir bank			17 466 cu. yds.
Volume in main portion of reservoir bank			15 474 ,,
Shrinkage in material excavated — Quantity			1 992 cu. yds.
— Percentage			11.4%
Material excavated for use in main portion of reservoir bank			17 466 cu. yds.
Quantity of solid stone in same			1 043 ,,
Percentage of stone removed from material excavated			5.9%

During the time when the work was well under way the average force employed on excavation and embankment was : —

Classification.	*Number Employed.*	*Rate of Pay.*	*Cost.*
General foreman	0.9	$4.00	$ 3.60
Subforeman	1.0	3.00	3.00
Timekeeper	.8	2.50	2.00
Water boys	7.0	.75	5.25
Carpenter	.5	2.50	1.25
Laborers	28.0	1.50	42.00
Teamsters	20.0	1.50	30.00
Horses	40.0	1.25	50.00
Daily pay-roll			$137.10

* Stones were removed only from material to be used in building embankment.

Proportional time only is given to general foreman, subforeman, timekeeper, and carpenter, the remainder of their time being devoted to other work in progress at the same time. The price for horses during 1901 was $1.50 each. The above force comprised three gangs on plowing and loosening and two gangs each on scraping, rolling, and spreading on the banks. From four to six scrapers were employed in each scraper gang, both gangs moving a maximum of 1 050 loads, or about 400 cubic yards per day. When the work was on the trimming and grading of banks this force was greatly reduced.

Concrete Masonry.

Concrete masonry (Class A), composed of 1 part of Portland cement, 2½ parts of sand, and 4 parts of stones, was used for the walls and bottom of the gate chamber, for the walls and floor of the gate vault in the standpipe foundations, and for cut-off walls on the pipe line.

Concrete masonry (Class B), composed of 1 part of Portland cement, 3 parts of sand, and 6 parts of stones, was used for the foundation of the standpipe and for the foundations of the steps of the gate chamber.

The bottom and slopes of the reservoir were lined throughout with two layers of concrete masonry separated by a layer of Portland cement plaster one-half inch in thickness.

Concrete masonry (Class C), composed of 1 part of American natural hydraulic cement, 2 parts of sand, and 5 parts of stones, was used for the under layer of concrete on the bottom of the reservoir.

Concrete masonry (Class D), composed of 1 part of Portland cement, 2½ parts of sand, and 6½ parts of stones, was used for the under layer of concrete on the slopes of the reservoir.

Concrete masonry (Class E), composed of 1 part of Portland cement, 2½ parts of sand, and 4 parts of stones, was used for the upper layer of concrete on the bottom and slopes of the reservoir.

It was specified that the cement should be properly tested, that the sand should be of approved quality, and that either clean gravel stones or crushed rock should be used in the aggregate. None of the stones were to be larger than two and one-half inches in their greatest diameter, and those used in the upper layer in the reservoir lining were limited to one and one-half inches.

It was also provided that this upper layer should be formed in blocks, half of the blocks, alternating in both directions, being first

made and allowed to set. The surface of these blocks was to be finished smooth and true to the slope required, and if plastering was necessary to obtain this, it was to be applied before the concrete had set. The whole cost of such plastering was to be included in the price stipulated for Class E concrete.

The quantity of concrete masonry paid for was that deposited in place in accordance with the plans and specifications.

About 4 350 barrels of cement were used on the work, 3 850 being Atlas Portland and the remainder being either Hoffman or Beach's natural cement. The Portland cement was put up in both barrels and bags, while the natural cement all came in bags. For testing, one sample was taken from the equivalent of each five barrels. All of the cement showed excellent results under the tests applied, which were those ordinarily employed for fineness, time of setting, tensile strength, and checking.

From the measurement of one hundred and fifty Atlas cement barrels the cubical contents between the heads was found to average 3.54 cubic feet per barrel, and from top to bottom with the heads out the cubical contents was 3.75 cubic feet.

In measuring stone and sand for the concrete, 3.7 cubic feet was the amount allowed per barrel by the specifications.

The following information concerning cement packages used on the work is given as the result of numerous determinations : —

Barrel full of cement (Atlas) weighs		402.8 lbs.
Barrel empty	18.5 lbs.	
Paper in barrel	.7 ,,	19.2 ,,
Net weight of cement in barrel		383.6 lbs.
Average weight per bag full of cement (Atlas)		96.6 lbs.
Average weight per bag empty		.6 ,,
Average weight of cement in bag		96.0 lbs.

Four bags of this cement were used as the equivalent of one barrel.

For the natural cement it was assumed that the net weight of cement per barrel should be about three hundred pounds.

Average weight per bag full of cement (Hoffman)	148 lbs.
Average weight per bag empty	2 ,,
Average weight of cement in bag	146 lbs.

Two bags of this cement were taken as the equivalent of one barrel.

Average weight per bag full of cement (Beach)	104.4 lbs.
Average weight per bag empty	.9 ,,
Average weight of cement in bag	103.5 lbs.

Three bags of this cement were taken as the equivalent of one barrel.

During 1900 the Portland cement was delivered on the work at the following cost per barrel: —

On board cars at East Milton	$2.11
Unloading, teaming, and storing (contract)	.12
	$2.23

During 1901 Portland cement was reduced in price, and cost per barrel on the work: —

On board cars at East Milton	$1.45
Unloading, teaming, and storing	.08
	$1.53

The natural cement cost: —

On board cars at East Milton	$1.00
Unloading, teaming, and storing	.08
	$1.08

Barrels returned to the factory are nominally worth twenty-five cents each, but on account of freight, broken and stolen barrels, etc., it is only safe to estimate on a rebate equivalent to five cents each for the whole number of barrels of cement bought, if care is taken to return the empty barrels.

If the cement is bought in bags of four per barrel, much greater saving is possible. The bags are nominally worth ten cents each, or forty cents per barrel, and as they can be packed in small space, are easily cared for and not readily damaged, they are worth an equivalent of thirty cents per barrel of cement bought after deducting all charges. On this basis the net cost of cement per barrel or per bag based on return of bags or barrels would be: —

	Delivered in Barrels.	*Delivered in Bags (4 bags = 1 barrel).*
Gross cost	$2.23	$2.23
Rebate	.05	.30
Net cost	$2.18	$1.93

Thus, if a large amount of cement is required which is to be used

quickly, there is a considerable saving in buying in bags. During 1900 no barrels or bags were returned. During 1901 the cement came in bags, which were nearly all returned.

Table No. 4.

SHOWING DISTRIBUTION OF CEMENT USED IN CONCRETE MASONRY FOR RESERVOIR LINING, GATE CHAMBER, AND FOUNDATION FOR STANDPIPE.

DESIGNATION.	Proportion.	No. of Barrels.	Quantities.		Amount Laid per Barrel of Cement.			Barrels of Cement per	
			Cu. Yds.	Sq. Yds.	Cu. Yds.	Cu. Ft.	Sq. Yds.	Cu. Yd.	Sq. Yd.
Concrete — Class A[1]	1:2½:4	377	279	...	0.74	20.	...	1.35	...
Concrete — Class B[1]	1:3:6	304	284	...	.94	25.4	...	1.07	...
Concrete — Class C[2]	1:2:5	500	400	...	.80	21.6	...	1.25	...
Concrete — Class D	1:2½:6½	664	615	...	.93	25.1	...	1.08	...
All except slope finish	1:2½:4	1 674	1 222	...	.73	19.7	...	1.37	...
Slope finish[3]	1:2½:4	112	100	3 600	.89	24.	32.1	1.12	0.03
Plaster[4]: Base, ½-in. thick	1:1	98	21.2	1 529	.22	5.9	15.6	4.6	.06
Base, ½-in. thick	1:2	240	73.5	5 293	.31	8.3	22.1	3.3	.05
Top finish, 3/32-in. thick	1:0	118	16.5	6 822	.14	3.8	57.8	7.2	.02
Granolithic walk: Base	1:3:5	110	90	695	.82	22.2	6.3	1.2	.16
Top finish	1:1½	73	19.3	695	.26	7.1	9.5	3.8	.11

[1] Gravel stone used in this concrete, broken stone used in remainder of concrete.

[2] Natural cement, all other Portland cement.

[3] "E" concrete left 1-in. low on slopes and smoothly finished with mixture having stone dust containing particles less than ⅜-in. diameter substituted for broken stone.

[4] Proportion changed from 1:1 to 1:2, as it was thought less likely to crack if more sand was used.

The sand used was for the most part of excellent quality, some coming from a pit in Avon and the remainder from Milton, either from a pit opened for the purpose or from an excavation for the Metropolitan sewer trench at the foot of the hill. The Avon sand weighed about 93 pounds per cubic foot, and although very clean and sharp was a little too fine for concrete work. The pit sand from Milton was of fair quality if care was taken to thoroughly strip the loam from the surface. The best sand was that which came from the sewer trench; this had all the requisite qualities, — coarse enough, sharp, and thoroughly clean, as it was excavated from a water-bearing stratum.

During 1900 the cost of sand delivered on the hill was $1.13 per cubic yard.
During 1901 the cost of sand delivered on the hill was $1.02 per cubic yard.

The greater part of the stone used in the concrete was obtained from the excavation and crushed on the ground. Previous to setting up the crusher, about seven hundred and fifty cubic yards of gravel stones were bought. These stones were taken from a gravel bank at the foot of the hill, passed through a power screen, supposedly rejecting sizes above two and one-half inches and those below three eighths of an inch. These stones were delivered on the hill for $1.13 per cubic yard. The average weight of this gravel was 111.3 pounds per cubic foot. It was very dirty, and before using it had to be thoroughly washed. The method employed was to fill an iron wheelbarrow with the stones, tip the barrow a little, and allow water from a hose to run through the gravel till the waste water was clear.

After the stone-crusher was put up, about two hundred cubic yards of gravel stones which had not been used were run through the crusher, the screen being set to reject sizes below one-half inch. This stone had lain spread out in the hot sun for several months and was thoroughly dry. The shaking it received going through the crusher removed all dirt, which with the fine stone dust was discharged in a pile by itself. This was the most inexpensive way of getting the stone into satisfactory condition, for beside the dirt there were a great many stones of sizes too large for the concrete work. The stone-crushing plant consisted of a twelve horse-power Hoadley engine belted to a 9 x 15 Farrel Foundry and Machine Company's crusher. The engine also ran the stone elevator and the revolving screen. The rated capacity of the crusher was

125 tons, or about 97 cubic yards per day; but if a third of this work was done without some part of the machinery giving out, it was considered a good day's work.

The stone bin had a capacity of about thirty cubic yards; it was separated into three compartments, one for sizes of stone up to one and one-half inches, a second for sizes between one and one-half inches and two and one-half inches, and a third for larger stone. The stones from the third bin were teamed back to the crusher and passed through it again. At first everything smaller than one and one-half inches was allowed to pass into the first compartment and used thus in the concrete; after a while, however, it was found that so great a quantity of stone dust was coming that it had the effect of adding more sand to the concrete mixture. This was probably caused by the condition of the jaws of the crusher, which were worn so smooth that they ground the stone rather than broke it. To remedy this the screen was arranged to discharge everything less than one-fourth inch in a pile by itself. A much better concrete resulted, and some of the fine screenings were later used in finishing the surface of the concrete on the slopes. The best results in all the concrete work were obtained by using the gravel stones which varied in size, or the "run of crusher" with the broken stone. Stones all of the same size — "road metal" — were always avoided. The stone crushed on the hill was mostly trap rock or a hard slate; this stone as crushed weighed, loosely packed, about 95 pounds per cubic foot. The $1\frac{1}{2}$ to $2\frac{1}{2}$ inch stone had 49 per cent. voids; the $1\frac{1}{2}$ inch and less, 43 per cent.; the $2\frac{1}{2}$ inch and less, — "run of crusher," — 46 per cent., and the gravel stones used during the first of the concrete work only 40 per cent., of voids. In estimating the amount of voids, the stone was thrown into a barrel, without ramming, and weighed. Water was then put into the barrel until it rose level with the surface of the stone. The barrel, stone, and water were then weighed. From the weight of the water its volume was calculated and the result assumed as the voids in the barrel of stone. It was estimated that the voids were decreased from seven to ten per cent. by ramming.

The cost of the stone-crushing and of the stone used in the concrete appears in Table No. 5. In this cost there appears a charge of forty cents per cubic yard for stone, concerning which the following explanation is made: In the spring of 1901, Messrs. Beckwith & Quackenbush, the contractors, having on hand considerable other

work at a distance from Quincy, made an arrangement with Messrs. Taylor, Carr & Andrews, of Boston, contractors for concrete work,

Table No. 5.

COST OF STONE USED IN CONCRETE.

Cost of Crushing Stone.		
Lumber in bin and platform, 9 M. spr., @ $20; 20 posts, 10″ x 4′, @ 50c. . .		$ 190.00
Labor		1 221.00
Rent of crusher	67 days, @ $3.00	201.00
Rent of engine	67 days, @ $1.50	100.50
Coal	32 tons, @ $4.45	142.00
Oil and supplies		50.00
Total cost		$1 904.50
Stone Crushed.		
From excavation		1 495 cu. yds.
Gravel stones		200 ,,
		1 695 cu. yds.
Cost of crushing stone	$\frac{1\,904.50}{1\,695}$ = $1.12 per cu. yd.	
Stone purchased	1 495 cu. yds., @ 40c.	$598.00
Gravel purchased	200 ,, @ $1.15	230.00
	1 695 cu. yds. cost	$828.00
Average cost of stone bought for crushing, per cu. yd.		$ .49
Average cost of crushing stone, per cu. yd.		1.12
Average cost of 1 695 cu. yds. stone used in concrete, per cu. yd.		$1.61
Cost per Cubic Yard of Stone Used in Concrete, 1901.		
Stone crushed on work	1 695 cu. yds., @ $1.61	$2 728.95
Gravel purchased	81 ,, @ 1.15	93.15
Crushed stone purchased	210 ,, @ 1.45	304.50
	1 985 cu. yds. cost	$3 126.60
Average cost per cu. yd. of stone used in concrete, 1901		$1.57
Cost per cu. yd. of gravel stones used in concrete, 1900		$1.13

to finish the concrete then remaining to be done. This included concrete of Classes C, D, and E, the plaster work, and the granolithic walk. The stone above mentioned had been saved by Messrs. Beckwith & Quackenbush to be crushed for the concrete, and part of their arrangement with the concrete contractors was to buy this stone as it lay for forty cents per cubic yard, based on the concrete measurements, together with about three hundred cubic yards of gravel stones that had been left over from the concrete work the previous year. The stones taken from the excavation were scattered over a considerable area, and they were very dirty from the clayey material which adhered to them. One of the principal causes of the high cost

of this stone was the expense of picking up and washing previous to crushing.

All of the concrete was mixed and placed by hand. Instead of using barrels to gage the sand and cement, boxes without bottoms were made which, when placed on the mixing board or mortar box and filled, would hold the quantity required to be used with one barrel of cement. The following sized boxes were found convenient: —

Proportions of Concrete.	Sand Box.		Stone Box.	
	Size.	Volume. Cu. Ft.	Size.	Volume. Cu. Ft.
1 — 2½ — 4	2′ 9″ x 2′ x 1′ 8″	9.25	5′ x 4′ 5¼″ x 8″	14.80
1 — 3 — 6	2′ 9″ x 2′ x 2′ 0″	11.10	5′ x 6′ 8″ x 8″	22.20
1 — 2 — 5	2′ 9″ x 2′ x 1′ 4″	7.40	5′ x 5′ 6⅝″ x 8″	18.50
1 — 2½ — 6½	2′ 9″ x 2′ x 1′ 8″	9.25	5′ x 7′ 2½″ x 8″	24.05

All concrete except that put upon the slopes was mixed moderately wet and rammed with a heavy, round-ended rammer until the mass quaked. From this method no "rat holes" were found in this concrete when the forms were removed. By the use of a spade to puddle the material next the forms, a firm, smooth finish was given to the faces. As to the probability of a concrete wall being impervious to water it is only necessary to state that there is in the gate chamber a partition 23 feet high, 11 feet wide, and 3 feet thick, against which there is a head of 19.5 feet of water, on which in dry weather there is not even moisture. No especial pains were taken with this wall, nor was any waterproofing used in it. On the slopes it was not possible to place a wet mixture of concrete, and here comparatively little water was used. This concrete was rammed with flat rammers about six inches square until moisture just appeared on the surface. If the ramming was longer continued or if the mixture was even a little too wet, the mass would flow down the slope. The method which gave the best results was to mix a batch rather wet and scatter it in a thin layer next the earth bank, on top of this placing the dry layer and ramming it well into the layer below. In all cases where concrete was laid on the earth, the surface was first thoroughly wet, so that the water might not be drawn from the concrete. As the upper layer on the slopes could not be put on wet enough to finish smoothly, it was left about one inch low and finished

like a granolithic walk with a wet mixture, troweled and worked until dry and hard. Great care was taken to apply this layer before the under concrete began to set. Usually it was applied at once, and in no case later than twenty minutes after the under layer was placed. This finishing layer was mixed in the same proportions as that used in the rest of this class of concrete, 1 — 2½ — 4, but stone dust and particles less than one-half inch in diameter were substituted for the one and one-half inch broken stone. The cost of this work is shown in detail in Table No. 6.

Table No. 6.

COST OF CONCRETE WORK.

CLASS A CONCRETE. 1 — 2½ — 5. — PORTLAND CEMENT.

279 cu. yds. in plan.

Cement	1.35 bbl., @ $2.23	$3.010
Sand	0.46 cu. yd., @ 1.13	.521
Stone	0.74 ,, @ 1.13	.840
Lumber for forms	M., @ 20.00	.495
Labor.		
General expenses	$ .202	
Forms	.586	
Mixing and placing	1.147	
		1.955
Cost per cu. yd.		$6.821

CLASS B CONCRETE. 1 — 3 — 6. — PORTLAND CEMENT.

284 cu. yds.

Cement	1.07 bbl., @ $2.23	$2.390
Sand	0.44 cu. yd., @ 1.13	.497
Stone	0.88 ,, @ 1.13	.994
Lumber for forms	M., @ 20.00	.127
Labor.		
General expenses	$ .154	
Forms	.214	
Mixing and placing	.967	
		1.335
Cost per cu. yd.		$5.337

CLASS C CONCRETE. 1 — 2 — 5. — NATURAL CEMENT.

400 cu. yds.

Cement	1.25 bbl., @ $1.08	$1.350
Sand	0.34 cu. yd., @ 1.02	.347
Stone	0.86 ,, @ 1.57	1.350
Lumber for forms	M., @ 20.00	.090
Labor.		
General expenses	$ .08	
Forms	.10	
Mixing and placing	1.17	
		1.350
Cost per cu. yd.		$4.487

Class D Concrete. 1 — 2½ — 6½. — Portland Cement.

615 cu. yds.

Cement	1.08 bbl., @ $1.53		$1.652
Sand	0.37 cu. yd., @ 1.02		.377
Stone	0.96 ,, @ 1.57		1.507
Lumber for forms	M., @ 20.00		.016
Labor.			
General expenses		$ .177	
Forms		.121	
Mixing and placing		1.213	
			1.511
Cost per cu. yd.			$5.063

Class E Concrete. 1 — 2½ — 4. — Portland Cement.

1 322 cu. yds.

		Cost per Sq. Yd.	Cost per Cu. Yd. Partial Quantity.	Cost per Cu. Yd. Total Quantity.
(*a*) Not including slope finish — 1 222 cu. yds.				
Cement	1.37 bbl., @ $1.53	. .	$2.09	$1.940
Sand	0.47 cu. yd., @ 1.02	. .	.48	.441
Stone	0.745 ,, @ 1.57	. .	1.17	1.088
Lumber	M., @ $20.00	. .	.25	.277
Labor.				
General expense		. .	.15	.143
Forms		. .	.26	.236
Mixing and placing		. .	1.53	1.416
Average cost per cu. yd. for 1 222 cu. yds.		. .	$5.93	. .
(*b*) Slope finish — 100 cu. yds. or 3 600 sq. yds.				
Cement		$ .048	$1.71	$ .129
Sand		.011	.39	.029
Stone		.026	.96	.073
Labor.				
Mixing and placing		.069	2.50	.189
Average cost per cu. yd. for 100 cu. yds.		. .	$5.56	. .
Average cost per cu. yd. for 1 322 cu. yds.		. .		$5.911
Average cost per sq. yd. for 3 600 sq. yds.		$ .154		

Plastering — 6 822 sq. yds.

		Cost per Sq. Yd.
Cement	0.07 bbl., @ $1.53	$ .103
Sand	0.012 cu. yd., @ 1.02	.012
Labor		.083
Burlap		.002
Average cost per sq. yd.		$ .200

Granolithic Walk — 695 sq. yds.

	Cost per Sq. Yd.	Cost per Cu. Yd.
1. Foundation, 232 cu. yds.		
Stone	$ .134	$ .40
Labor, placing	.502	1.50
Average cost per sq. yd.	$ .636	
Average cost per cu. yd.		$1.90

		Cost per Sq. Yd.	Cost per Cu. Yd.
2. Concrete Base, 90 cu. yds.			
Cement	1.22 bbl., @ $1.53	.242	$1.87
Sand	0.50 cu. yd., @ 1.02	.066	.51
Stone	0.84 cu. yd., @ 1.57	.170	1.32
Labor		.450	3.48
Average cost per sq. yd.		$ .928	
Average cost per cu. yd.			$7.18
3. Top Finish.			
Cement	0.11 bbl., @ $1.53	.168	
Sand	0.022 cu. yd., @ 1.02	.022	
Lampblack		.008	
Labor		.149	
Average cost per sq. yd.		$ .347	
Total average cost of walk per sq. yd.		$1.911	

In connection with the use of stone dust in mortar, it is interesting to note that briquettes in which it is substituted for sand show a much higher tensile strength, and, in the work on the East Boston Tunnel, stone dust has entirely taken the place of sand.

All the concrete when laid was kept thoroughly wet. After it was set hard enough not to be washed, it was sprinkled once an hour during the day and sometimes into the evening for at least two days. After this, for three or four days, it would be well wet from four to five times per day, and then once in the morning and again in the afternoon, until covered with other concrete or until the work was completed.

The ordinary composition of a concrete gang was one subforeman, two men gaging materials, two men mixing mortar, three men turning concrete, three men wheeling concrete, one man placing, and two men ramming. Two concrete gangs were usually employed, and under ordinary conditions placed about twenty cubic yards per day per gang, or about 1.43 cubic yards per day per man employed. Beside these gangs, three plasterers and three helpers were employed on the slope finishing: on the bottom the material was put in so wet that one plasterer was able to finish for a gang of concrete men. This concrete was mixed on a wooden mixing platform about twelve feet square, and was always turned three times before being placed.

The upper layer, on both bottom and slopes, was put in in blocks, one half, alternating in both directions, being first made and allowed to set. On the bottom these blocks were ten feet square, and on the sides they were about eight by ten feet. The following method was employed in laying the concrete in these blocks: The surface of the plaster layer was laid off into parallelograms of required size by

spots of black paint. On two adjacent lines of spots, three- by four-inch scantlings, with the four-inch side vertical and just ten feet apart inside to inside, were laid completely across the reservoir. On the next two rows of spots the same thing was done. This left a clear space of ten feet between scantlings in every other row. In these ten-foot rows crosspieces were laid so that every other square thus formed would be of the required length. These squares were filled with concrete first, and it was allowed to set. When ready the crosspieces were removed, and the remaining spaces in the ten-foot sections were filled. After this all the longitudinal scantlings were removed, leaving vacant rows ten feet wide alternating with ten-foot rows filled with concrete. The vacant rows were now similarly blocked off by crosspieces, sand bags being used to keep the crosspieces in place. In order to hold the scantlings on the slopes, stakes were driven through the under layer into the bank. These stakes were so placed that they came in the alternate rows which were last to be filled. When the concrete in the rows first placed was well set the forms were removed and the stakes drawn by lever and chain. The holes were then carefully filled with grout and plastered before the remaining concrete in the upper layer was placed.

Between the two layers of concrete a half-inch plaster layer, previously mentioned, was placed, in order to provide a barrier impervious as possible to the flow of water. This layer was put down generally in strips about four feet wide and of any convenient length. The thickness was gaged by strips of wood one-half inch thick laid on the concrete, and the plaster brought level by a straight-edge. This coating was worked to a smooth, hard finish, similar to that on a granolithic walk and by the methods there employed. At first the proportions used were 1 part of Portland cement to 1 part sand, for the greater part of the layer, with a top finish of 4 parts cement to 1 part sand. Later, when cracks appeared, the proportion was changed to 1 part cement to 2 parts sand, and somewhat better results were obtained. Most of the cracks came where concrete laid at different times in the under layer was joined. These cracks were thoroughly washed with grout before being covered with the upper layer of concrete. For keeping the plastering wet, long strips of burlap were used. These were saturated with water and laid over the plaster as soon as it was hard enough to bear the weight. They formed an excellent covering, as they retained the

Fig. 1. — Reservoir Lining under Construction: Under Layer of Concrete.

Fig. 2. — Reservoir Lining under Construction: Plaster Work and Upper Layer of Concrete.

moisture for a long time and kept the direct rays of the sun from the work. The custom was to keep these coverings on the plaster for about two days and after that to keep it wet and cool by sprinkling. Beside the plaster between the layers of concrete, the upper edge of the concrete against the bank was also plastered as a precaution against infiltration of surface water and consequent damage by frost.

Before placing any mortar for plastering, the surface of the concrete layer was thoroughly swept with a heavy rattan stable broom, wet, again swept, and then moistened just before placing the mortar. It is thought that the plaster layer is thoroughly bonded to the concrete, and in several places where breaks were made the plaster could not be removed separately, but both concrete and plaster came together.

The cost of the plaster work is found in Table No. 6. Three gangs, each consisting of a plasterer and helper, were employed on this work. The average amount of completed plaster work per gang per day, under ordinary conditions, was about seven hundred square feet.

The concrete work in progress is shown in Plate III, Figs. 1 and 2, and the inside of the completed reservoir on Plate VI, Fig. 1.

After the banks were built a granolithic walk was constructed on top, entirely around the reservoir. This walk is six feet wide, and was laid in blocks about six feet long. It has a foundation about twelve inches thick of stones of various sizes up to about six inches in diameter. On top of this was spread about an inch of cinders or fine broken stone, which was thoroughly rolled and consolidated. The concrete layer resting on this foundation is four inches thick at the sides and an inch thicker in the middle. It was placed in one layer, mixed in the proportion of 1 part Portland cement, 3 parts sand, and 5 parts broken stone. Each block is separated from the one adjoining by a sand partition about three eighths of an inch thick. At first the concrete was put down in a continuous layer and then divided into blocks by pieces of steel about two feet long driven down through the layer. As it was almost impossible to get straight lines with these concrete knives, and as it was impracticable to lay the walk in alternate blocks on account of the width of the bank and the steep slopes, a method was devised of using templets between adjacent blocks. These were pieces of steel six feet long and three-eighths of an inch in thickness, curved on top

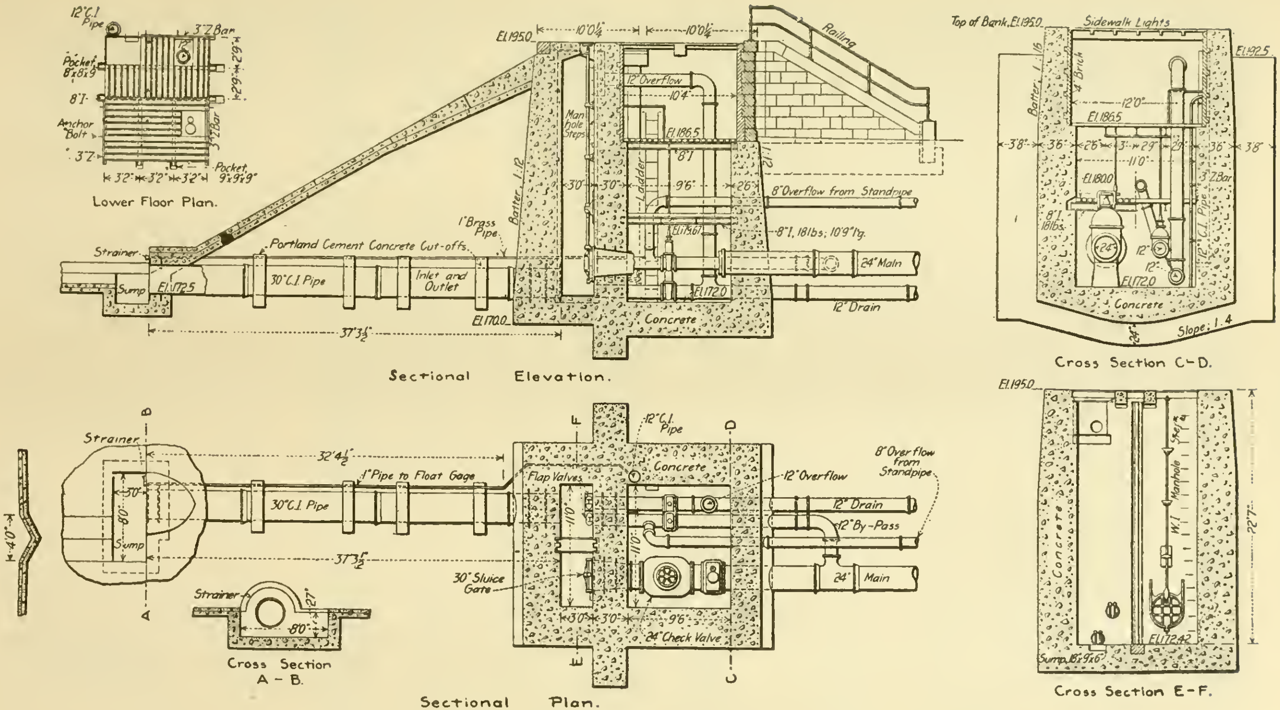
to the required arc of the surface of the finished walk. The only drawback observed with this method was the care necessary to be taken to avoid running the finishing tool over the top of the templet and thus neglecting the surface adjoining, in which case the top finish immediately against the iron would not be so thoroughly consolidated as other portions of the surface, and was liable to crack. On top of the concrete layer was placed the wearing surface one inch thick, which was composed of 1 part Portland cement and $1\frac{1}{2}$ parts sand, with one pound of lampblack per barrel of cement to give the slate-colored appearance. After this layer had been thoroughly worked, the templets were removed, the space filled with sand, and a finishing tool for rounding off the edges run around the block. The cost of this work in detail is shown in Table No. 5.

The average gang employed on the granolithic walk, exclusive of the foundation, was six laborers and a single team on the concrete, and two masons and a tender on the finish coating. The average amount of walk finished per day was sixty linear feet, six feet wide.

The cost of the reservoir to the Commonwealth is shown in Table No. 9.

GATE CHAMBER.

As previously noted, this structure is located in the west bank of the reservoir. The front of the chamber, the steps leading to the top of the bank, and the sills for stop planks are of best quality Quincy granite. The tops of the sills, the treads of the steps, the coping and other trimmings are of six-cut dimension stone. The exposed portions of the front and wing walls are faced with ashlar of an average depth of ten inches, having edges pitched to a true, straight line. The stones were laid in Portland cement mortar, the proportions being 1 part cement to $2\frac{1}{2}$ parts sand. On the dimension stone the joints were three-eighths inches thick and on the ashlar one-half inch, for a distance not less than six inches from the face. After laying, all joints were raked out and pointed with 1 to 1 Portland cement mortar. It was late in the fall and very cold when this was done. In order to work quickly the pointing mortar was mixed very wet, and consequently dripped over the faces of the stone, giving a very unsightly appearance.



DETAILS OF GATE CHAMBER AND PIPE CONNECTIONS.

FIG. 3.

When work was resumed in the spring the matter of cleaning the stonework was greatly delayed, and when at last it was done, it was found necessary to entirely remove the pointing, wash the stone with acid, and repoint the joints. This work cost about fifty dollars. Men thoroughly accustomed to this kind of work were employed, as there was great danger of burning and thus spoiling the stone. Muriatic acid was used diluted with water in the proportion of 1 part acid to 2 parts water. This mixture was applied to the stone with paint brushes which had outlived their original usefulness. About four gallons of acid were used. Two men did the work, being employed five days removing the pointing, two days cleaning the stone, and two days repointing. About five hundred and sixty square yards of stone facing were gone over in this time.

Inside the gate chamber, above the level of the upper floor, the walls were lined with brick tied to the concrete backing with rows of headers. This work was left in the same condition as the stonework, and in the spring was given a coat of brick stain. This gave it an excellent appearance, and was less expensive and more satisfactory than cleaning with acid.

Except for the two floors, the woodwork in door and frame, and the ironwork in floor beams, wall castings, stop-plank grooves, etc., the remainder of this structure is of concrete.

The chamber is covered with Aberthaw sidewalk lights of standard construction. The top of this covering is on a level with, and forms a part of, the walk about the reservoir.

The gate chamber is divided vertically into two parts — an inlet and outlet chamber, and the gate chamber proper. The effective height of this structure is about twenty-two feet. In plan the water chamber is three by eleven feet and the gate chamber nine and one-half by eleven feet. This latter part is divided into three stories by two floors of six-inch hard pine, resting on Z-bars embedded in the concrete.

The piping and system of valves in the chamber is best explained by the sectional plans, Fig. 3. The main feed to the reservoir is through a twelve-inch by-pass from the twenty-four inch main. On the main, just beyond the by-pass branch and toward the reservoir, is a twenty-four inch gate valve, and beyond this a twenty-four inch check valve, so set as to open only when the head on the main falls below that in the reservoir. The reservoir is thus a storage basin, to be called on only in emergency. Between the check valve

and the water chamber is a sluice valve, and by shutting this and the twenty-four inch gate valve, the check valve can be readily overhauled.

In the bottom of the chamber is a twelve-inch pipe for draining the reservoir, into which the twelve-inch overflow pipe discharges. A closed gate on the drain on the reservoir side of the overflow pipe allows this pipe free discharge at all times. The overflow from the standpipe discharges into the reservoir freely, there being no valves on this line to be carelessly left closed. Flap valves are placed on the reservoir ends of both the drain and the by-pass from the twenty-four inch main, so that the valves on these pipes can be overhauled without drawing down the reservoir.

The inlet and outlet pipe from the gate house to the reservoir is thirty inches in diameter. This pipe is laid in a trench, dug through the undisturbed hard pan, and is surrounded by several concrete cut-off walls, well bonded into the sides of the trench.

Inside the chamber is a vertical pipe twelve inches in diameter, for a float gage. This pipe is connected with the water in the reservoir by a brass pipe, having a strainer on the reservoir end.

The actual cost of erecting the gate chamber is shown in Table No. 7, and its total cost to the Commonwealth is shown in Table No. 9.

A front elevation of the completed gate chamber is shown on Plate II, Fig. 2.

Table No. 7.

GATE CHAMBER — COST.

The Commonwealth furnished valves, pipes, specials, iron work, screens, and stop planks. Excluding the cost of these, but including the expense of setting the wall castings, the actual cost of the gate chamber was: —

Earth excavation	630 cu. yds.,	@ $ .944		$ 594.72
Concrete masonry, Class "A"	243 ,,	@ 6.820		1 657.26
Concrete masonry, Class "B"	37 ,,	@ 5.340		197.58
Granite Masonry.				
Stone delivered on work			$1 000.00	
Cement (estimated)	8 bbls.,	@ $2.23	17.84	
Sand (estimated)	3 cu. yds.,	@ 1.13	3.39	
Labor			168.68	
Rent of derrick	5 weeks		50.00	
Repointing and cleaning			50.00	
				1 289.91

Brick Masonry.			
Labor		$60.90	
Brick	3 500, @ $10.00 per M.,	35.00	
Cement (estimated)	10 bbls., @ $2.23	22.30	
Sand (estimated)	4 cu. yds., @ 1.13	4.52	
			$122.72
Woodwork and Covering.			
Aberthaw covering	132 sq. ft., @ $1.50	$198.00	
Door and frame		30.00	
Hard pine lumber in floors		25.00	
Hardware		10.00	
Labor		38.00	
			$301.00
			$4 163.19

STANDPIPE.

On July 17, 1900, the following bids for building the standpipe were received, and the contract was awarded to the lowest bidder, Walsh's Holyoke Steam Boiler Works, of Holyoke, Mass. : —

Canvass of Bids for Building Standpipe.

Bidders.	Amount.	Cost per Net Pound.
Walsh's Holyoke Steam Boiler Works, Holyoke	$4 425.00	$0.038
E. Hodge & Co., East Boston	4 498.00	.039
Edw. Kendall & Co., Cambridge	5 939.00	.051
R. D. Wood & Co., Philadelphia	6 720.00	.073

The following details relate to materials and methods of construction as provided in the specifications : —

The standpipe is cylindrical, 30 feet in diameter and 64 feet 4 inches high. It consists of a bottom of plates, and sides composed of thirteen courses of plates, each course, except the last, being five feet in height. Each course is of the same diameter at its top and bottom, and each alternate course is built inside those immediately above and below it, the inside radius of the lowest course and the outside radius of the next above it being each fifteen feet.

The bottom plates are three-eighths of an inch thick. In the vertical courses the plates have the following thicknesses : —

Lowest course	$\frac{9}{16}$	inch.	6th and 7th courses	$\frac{3}{8}$	inch.
2d and 3d courses	$\frac{1}{2}$	„	8th and 9th „	$\frac{5}{16}$	„
4th and 5th „	$\frac{7}{16}$	„	10th to 13th „	$\frac{1}{4}$	„

The lowest course is connected to the bottom on the inside by a $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$ inch angle, and the top course is stiffened by a $4 \times 3 \times \frac{3}{8}$ inch angle inside. The bottom angle has closely butting joints, none of which come within twelve inches of any joint in bottom or side plates. The plates are of open hearth steel, containing not more than 0.06 per cent. of phosphorus, and having an ultimate tensile strength of not less than 54 000 nor more than 62 000 pounds per square inch; an elastic limit of not less than one half the ultimate strength ; an elongation of not less than 26 per cent. in eight inches, and a reduction of area not less than 50 per cent. at fracture. The steel was to admit of bending cold, flat upon itself without fracture, both before and after being heated cherry-red and quenched in water. Provision was also made for such other tests as might be necessary. Laminations in plates or rolled shapes were sufficient cause for rejection, and plates were required to be free from slag, scale scabs, etc. No plate was to be deficient in weight more than two per cent. of the weight due the specified thickness, on a basis of forty-one pounds per square foot for plates one inch thick, and no part of any plate was to be one thirty-second of an inch below the required thickness.

The rivets are of best quality rivet steel and are all machine driven, except those in inaccessible locations and a very few which were driven while the pneumatic machines were out of order. Each course is composed of eight plates, and the joints in each course break at least three feet. The vertical joints in the five lowest courses have outside butt-straps, while in the remaining eight courses these joints are lapped. All the vertical butt-straps have two rows of rivets on each side of the joint. The vertical joints in the sixth to the ninth courses inclusive are double riveted, and those in the remaining courses single riveted. The horizontal girth joints are lapped and single riveted, and the joints in the bottom are made with inside butt-straps with one row of rivets on each side of the joint. The size and pitch of the rivets in the several courses, in inches, is shown below.

	Horizontal Joints.			Vertical Joints.			Notes.
	Size.	Pitch.	Width Lap.	Size.	Pitch.	Width Lap.	
Bottom plates	$\frac{3}{4}$	$2\frac{1}{8}$	$6\frac{1}{2}$	. .	. .	. . .	In the bottom plates and in the vertical joints, in courses 1 to 5 inclusive, the width of lap is the total width of the cover plate for butt-joints — in all other cases it is the lap of one plate on the one adjacent. All dimensions are in inches. The thickness of the cover plates was the same as that of adjoining plates in tank.
Bottom angle	$\frac{7}{8}$	$2\frac{3}{8}$	. . .	. .	. .	. . .	
1st course . .	$\frac{7}{8}$	$2\frac{3}{8}$	$3\frac{1}{2}$	$\frac{7}{8}$	$2\frac{7}{8}$	$10\frac{3}{4}$	
2d ,, . .	$\frac{7}{8}$	$2\frac{3}{8}$	$3\frac{1}{8}$	$\frac{7}{8}$	$2\frac{7}{8}$	$10\frac{1}{4}$	
3d ,, . .	$\frac{7}{8}$	$2\frac{3}{8}$	3	$\frac{7}{8}$	$2\frac{7}{8}$	$10\frac{1}{4}$	
4th ,, . .	$\frac{7}{8}$	$2\frac{3}{8}$	$2\frac{7}{8}$	$\frac{3}{4}$	$2\frac{3}{4}$	$9\frac{1}{4}$	
5th ,, . .	$\frac{3}{4}$	$2\frac{1}{8}$	$2\frac{3}{4}$	$\frac{3}{4}$	$2\frac{3}{4}$	$9\frac{1}{4}$	
6th ,, . .	$\frac{3}{4}$	$2\frac{1}{8}$	$2\frac{5}{8}$	$\frac{3}{4}$	$2\frac{5}{8}$	$4\frac{1}{4}$	
7th ,, . .	$\frac{3}{4}$	$2\frac{1}{8}$	$2\frac{1}{2}$	$\frac{3}{4}$	$2\frac{5}{8}$	$4\frac{1}{4}$	
8th ,, . .	$\frac{3}{4}$	$2\frac{1}{8}$	$2\frac{3}{8}$	$\frac{5}{8}$	$2\frac{5}{8}$	4	
9th ,, . .	$\frac{5}{8}$	$1\frac{11}{16}$	$2\frac{1}{4}$	$\frac{5}{8}$	$2\frac{5}{8}$	4	
10th ,, . .	$\frac{5}{8}$	$1\frac{11}{16}$	$2\frac{1}{8}$	$\frac{5}{8}$	$1\frac{11}{16}$	2	
11th ,, . .	$\frac{5}{8}$	$1\frac{11}{16}$	2	$\frac{5}{8}$	$1\frac{11}{16}$	2	
12th ,, . .	$\frac{5}{8}$	$1\frac{11}{16}$	2	$\frac{5}{8}$	$1\frac{11}{16}$	2	
13th ,, . .	$\frac{5}{8}$	$1\frac{11}{16}$	2	$\frac{5}{8}$	$1\frac{11}{16}$	2	
Top angle . .	$\frac{3}{4}$	4	3	. .	. .	. . .	

All calking edges were beveled by a planer, at least one-fourth inch of metal being removed. All shaping was done by cold rolling, no heating and hammering being allowed. No work was done below a blue or black heat, scarfing being only allowed in the upper eight courses, and the parts scarfed afterwards being thoroughly annealed. All eccentricity in rivet holes greater than one thirty-second of an inch was reamed, the use of a drift-pin to force the holes to coincide not being allowed.

The bottom of the tank is fitted with openings for the inlet and outlet pipe and a drain pipe. At the top there is a connection for the overflow pipe. For details see Fig. 4.

All shop work was done at the boiler works at Holyoke, and the parts were shipped to the work ready for erection, which was begun October 15. The concrete foundation for the standpipe was all ready (see Fig. 5), having been constructed by the contractors for the reservoir, as previously noted. On this foundation, and resting on rivet kegs directly over its final location, the bottom and first course of vertical plates were riveted together, and the inside seams

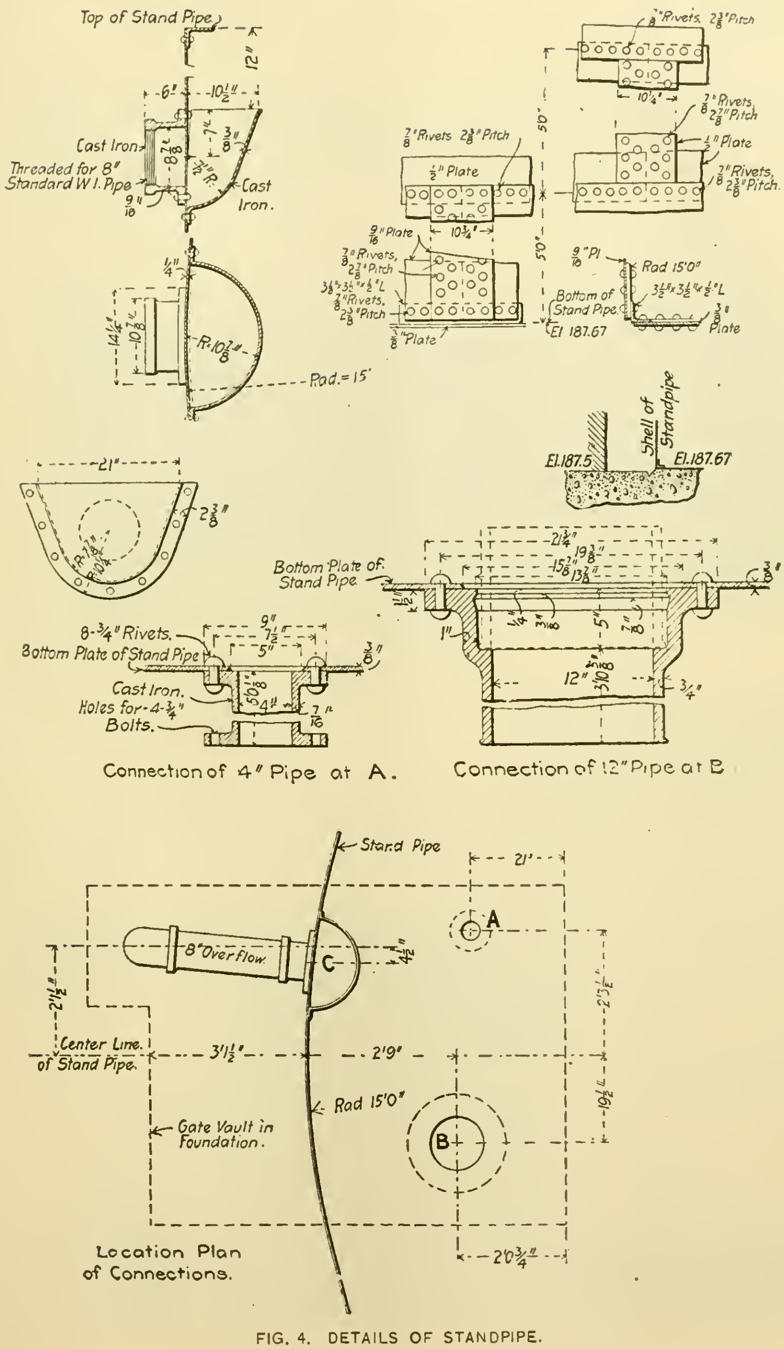
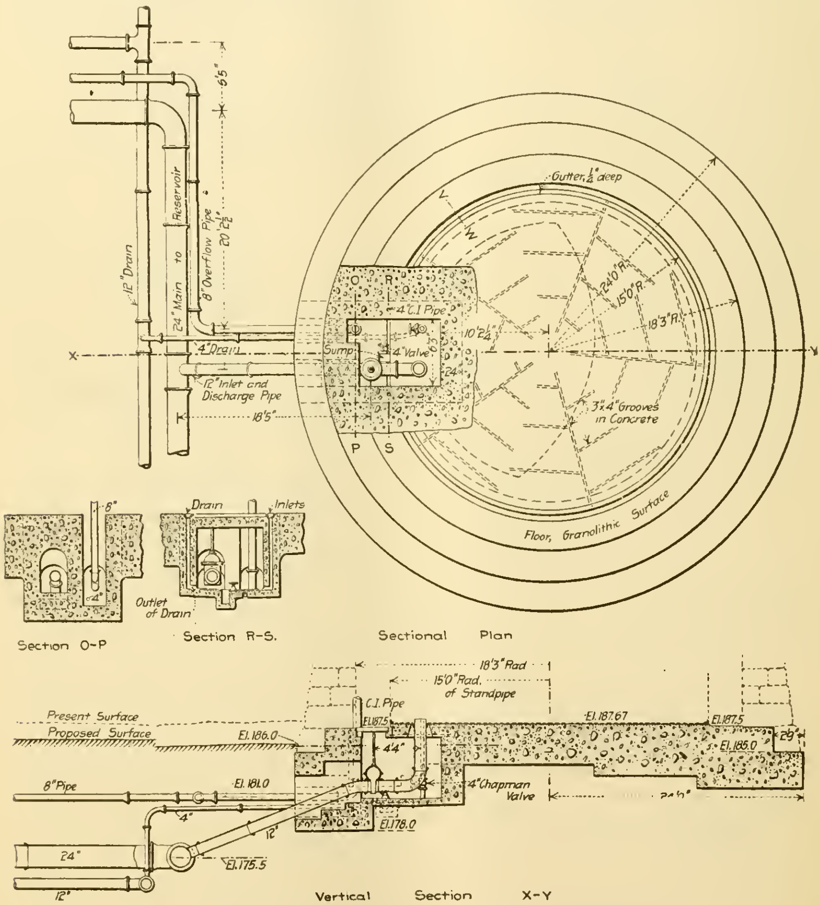


FIG. 4. DETAILS OF STANDPIPE.

calked (see Plate IV, Fig. 1). The bottom was then covered with water to the depth of the angle iron — about three and one-half inches — and the under side carefully examined for leaks. One or two damp spots were found, and after the water was drawn off these places



DETAILS OF FOUNDATION FOR STAND-PIPE AND MASONRY TOWER

FIG. 5.

were recalked. This portion was then lowered by hydraulic jacks and blocking to the concrete foundation.

The work of putting together the remainder of the plates was then begun. It was provided in the specifications that water might be ad-

FIG. 1. — RIVETING BOTTOM OF STANDPIPE.

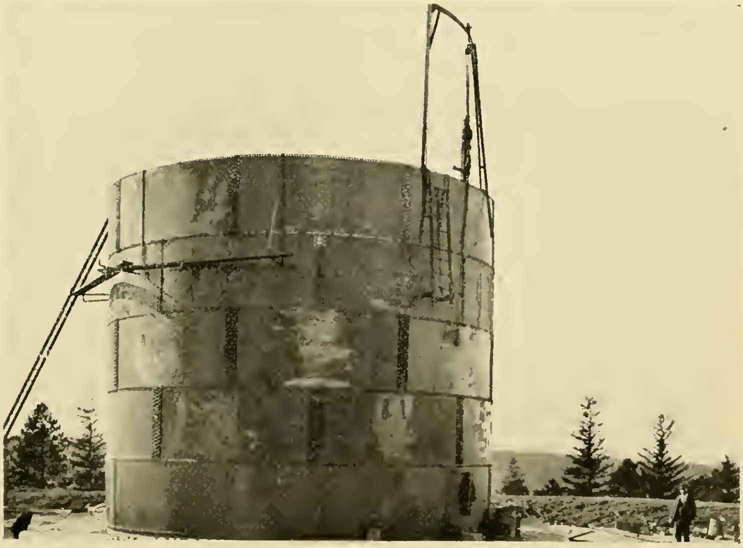


FIG. 2. — STANDPIPE PARTIALLY ERECTED.

mitted and a floating platform be used for erection. The contractor, however, preferred to use inside and outside platforms swinging from the top of the last plates set up, and for hoisting the plates he used a gin-pole bolted to seams in this course. This pole was of such length that a block at its top would be about nine feet above the top of the course to which the pole was bolted. The hoisting rope passed through a movable block, in which was the hook carrying the plate to be raised, through the stationary block at the top of the pole, down to another block temporarily fastened about five feet above the bottom of the tank, across the tank to a block permanently fastened directly opposite the manhole, through which the rope passed to a winch operated by hand. The method of erection and the partially completed tank are shown on Plate IV, Fig 2.

The riveting and calking, except for some special reason, were all done by pneumatic machines. Power was furnished by a twenty-five horse power boiler, carrying a steam pressure of eighty pounds, and a twelve horse-power Clayton Air Compressor, furnishing a pressure of from one hundred to one hundred and ten pounds per square inch.

All the calking was done by a hand machine, using a round-nosed tool. The tendency was to use a thin tool and just upset the calking edge of the plate or strap. The method required was to use a tool with a thicker edge, starting it at about the middle of the plate edge and working here until the inner portion of this edge was driven against the other plate. The calking proceeded much slower by this method, but much tighter and more permanent joints were obtained.

For driving the rivets hand machines were used almost entirely, using a dolly bar to drive against. It had been intended to use a larger and more powerful tool, called a "gap riveter," hanging from a frame resting on top of the plates as erected. This machine did not work satisfactorily and was soon abandoned. If this machine had been used, it was planned to keep the rivet work just behind the erection of the plates, working up from the bottom. On account of not using the "gap riveter," and also on account of repairing the air compressor, which gave continual trouble,— not being large enough for the work,— it was decided to set up all the plates with bolts and then do the riveting, beginning at the top and working down.

The erection was finished November 20, all riveting and calking was done December 13, and the painting was finished a few days later.

After the work was done the tank was filled with water to a depth

of about six feet. The bottom of the tank was now resting on the rivet heads on top of the concrete foundation. The space between the bottom plate and the top of the concrete at the edge of the tank was calked tightly with gasket such as is used in pipe joints. Three by four inch grooves had been left in the top of the concrete foundation for use in pumping cement grout under the tank. The openings to all of these grooves except one were tightly closed with wooden plugs, and by means of a pump the grout was forced under the tank through this opening until it appeared at all of the other openings when the plugs were removed. The pump was then attached to each opening in turn and grout forced in until further pressure forced out the gasket near the opening. About fifteen barrels of Portland cement were used on this work.

After this was done the standpipe was filled with water, and several places on the sides where leaks appeared were calked. Several leaks about the bottom gave the most trouble, and it was necessary to draw off the water and do some inside calking before they could be stopped. On filling the tank again only a dripping was apparent about the bottom, and by the next spring this had stopped, and the tank is now apparently water-tight.

The cost of the work is shown in Tables Nos. 8 and 9.

Table No. 8.

COST OF FURNISHING MATERIAL AND ERECTING STANDPIPE, 1900.

Labor.			
Assembling plates	$383.33		
Riveting	488.38		
Calking	111.95		
Painting	47.36		
Cost	$1 031.02	Cost per lb.	$ .00885
Materials.			
55 tons steel plate, @ $50.00	$2 750.00		
1 ton L iron	107.00		
70 kegs rivets, @ $2.75	192.50		
Bolts used in erection	10.00		
Moving material to and from shop and cars	250.00		
Freight on material	180.00		
Cost	$3 489.50	Cost per lb.	.02996
Total cost	$4 520.52	Total cost per lb.,	$ .03881
Estimated cost of field plant			$1 600.00

Force employed and rate, —

1 foreman, @ $3.50; 1 calker, @ $3.00; 1 riveter, @ $2.50; 1 engineer, @ $2.50; 2 heaters, @ $2.00; 3 helpers, @ $1.80.

Table No. 9.

COST OF WORK TO COMMONWEALTH OF MASSACHUSETTS.

(To January 1, 1902.)

Reservoir.			
Earth excavation, 30 100 cu. yds.		$11 438.00	
Rock excavation		52.00	
Concrete masonry		15 044.50	
Plastering		1 705.60	
Granolithic walk		1 313.17	
Seeding		21.00	
Railing and labor		425.75	
Miscellaneous: plastering, grading, etc., extra		461.54	
			$30 461.56
Gate Chamber.			
Earth excavation, 630 cu. yds.		$ 239.40	
Concrete masonry		2 232.00	
Granite masonry		855.20	
Brick masonry		115.56	
Pipe connections — labor		100.00	
Woodwork and covering of gate chamber		480.00	
Laying water pipes, 30″ and 24″		29.90	
Furnishing water pipes, 30″, 24″, 12″, and 12″ drain		487.09	
Valves		1 289.09	
Specials and wall castings		508.80	
Stop-planks, screens, float gage, etc.		253.02	
Iron work: beams, ladders, M. H. frames and covers, etc.		310.00	
Lead, freight, etc.		55.34	
Labor: laying drain, teaming pipe, etc., extra		761.71	
Extra on stonework, recutting steps		47.28	
			7 764.39
Standpipe.			
Foundation.			
Excavation, 1 355 cu. yds.	$514.90		
Concrete masonry	1 704.00		
Grouting under standpipe	133.26		
		$2 352.16	
Pipe Connections.			
Furnishing 4″, 8″, and 12″ cast-iron pipe	$111.80		
Labor	20.00		
Specials and valves	207.57		
		339.37	
Standpipe, furnishing and erecting (Walsh contract)		4 529.72	
Masonry tower (McCoy contract), to January 1, 1902		11 774.05	
			18 995.30
Miscellaneous.			
Extension of Section 21 of pipe line.			
Pipe trench excavation, 249 cu. yds.		$94.62	
Laying 24″ pipe		44.91	
24″ valve, frame and cover for M. H.		237.82	
Furnishing 24″ pipe		293.78	
General expense: fence, rent of land, spur track, etc.		492.54	
Driveway (unfinished), to January 1, 1902		62.20	
Extra work: grading land, disposal of surplus, driveways, etc.		603.08	
			1 828.95
Total cost to January 1, 1902			$59 050.20

MASONRY TOWER.

The bids for building the masonry tower about the standpipe were opened May 14, 1901, and on May 23 the contract for furnishing all the materials and doing all the work was awarded to the lowest bidder, Mr. J. E. McCoy, of Boston.

The canvass of bids received for this work was : —

Bidders.	*Amount.*
John Carlman, Quincy	$31 000.00
Fessenden & Libby, Boston	30 500.00
James H. Jacobs, Boston	24 973.00
James E. McCoy, Boston	24 790.00

The following are the principal items included in this work, as estimated from the drawings : —

Rubble stone masonry	925 cu. yds.
Dimension stone masonry	275 ,,
Iron and steel Work	14 tons
Granolithic observation roof	90 sq. yds.

The plans, sections, and elevations of this work are shown on Figs. 6 and 7.

The tower is about seventy-seven feet high from the surface of the ground to the top of the caps of the merlons. The inside of the wall is plumb, while the outside face has such a batter that the thickness of the wall is four and three-quarters feet at the top of the standpipe foundation, three and five-tenths feet at a point nine and five-tenths feet above this foundation, and two feet just below the cornice arches. The merlon caps and embrasure sills are the largest and heaviest stones used. There are sixteen each of these, and each stone weighs about three and one-half tons.

Beside its general design, the principal architectural feature of the tower is the arch over the entrance (Plate V, Fig. 2). This has a clear span of eight feet five inches, and a rise equal to one half the span. Its face is curved and battered to conform with the outside surface of the wall, and in this respect presents a form of arch not frequently encountered. In the drawings the joints of the several arch stones were laid out to be cut on planes normal to the vertical plane of projection of the arch rather than on planes radiating from the center of the tower. On account of the curved surface horizontally and the batter vertically, this was thought the easiest way of cutting

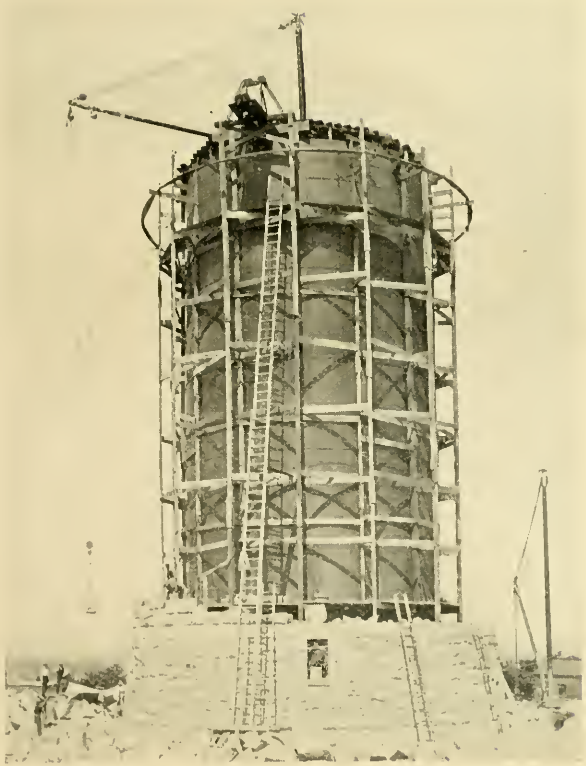


FIG. 1.—MASONRY TOWER DURING ERECTION.

FIG. 2.—ENTRANCE TO MASONRY TOWER.

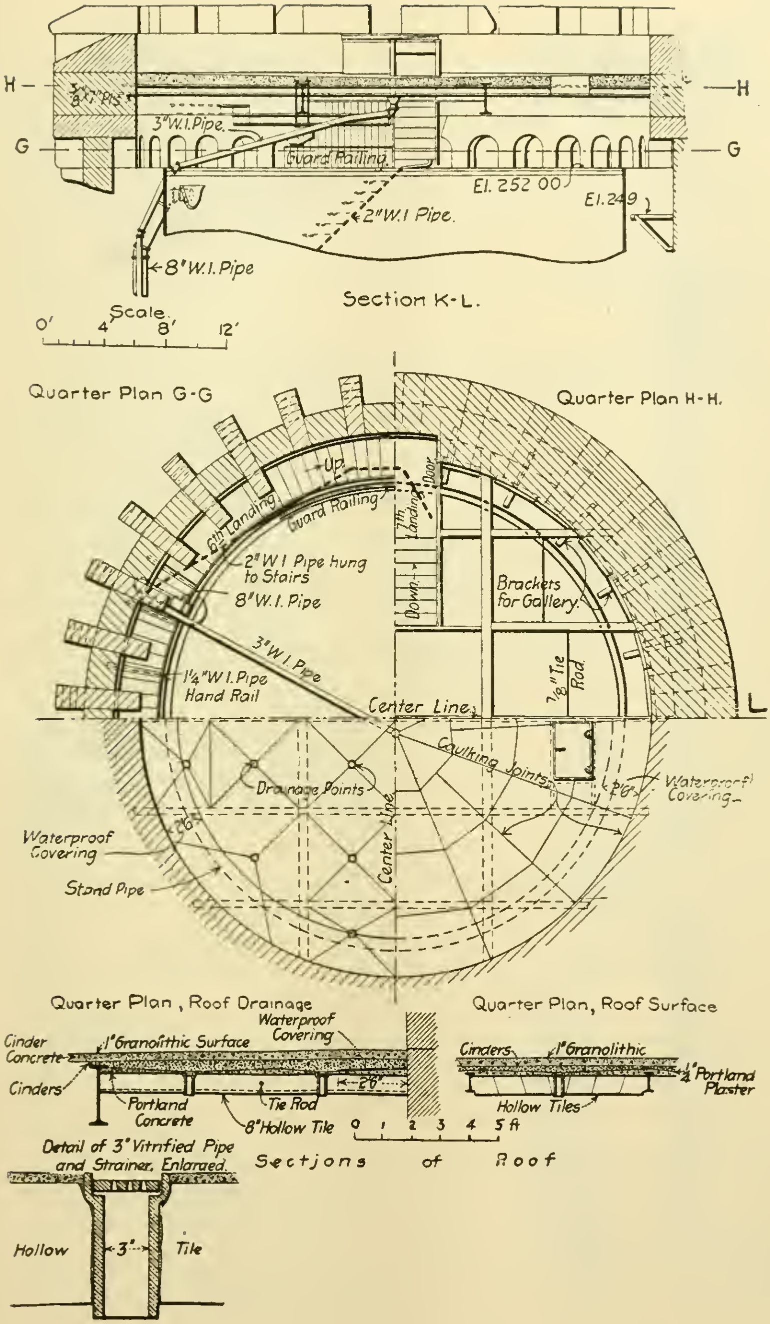


FIG 6. DETAILS OF MASONRY TOWER.

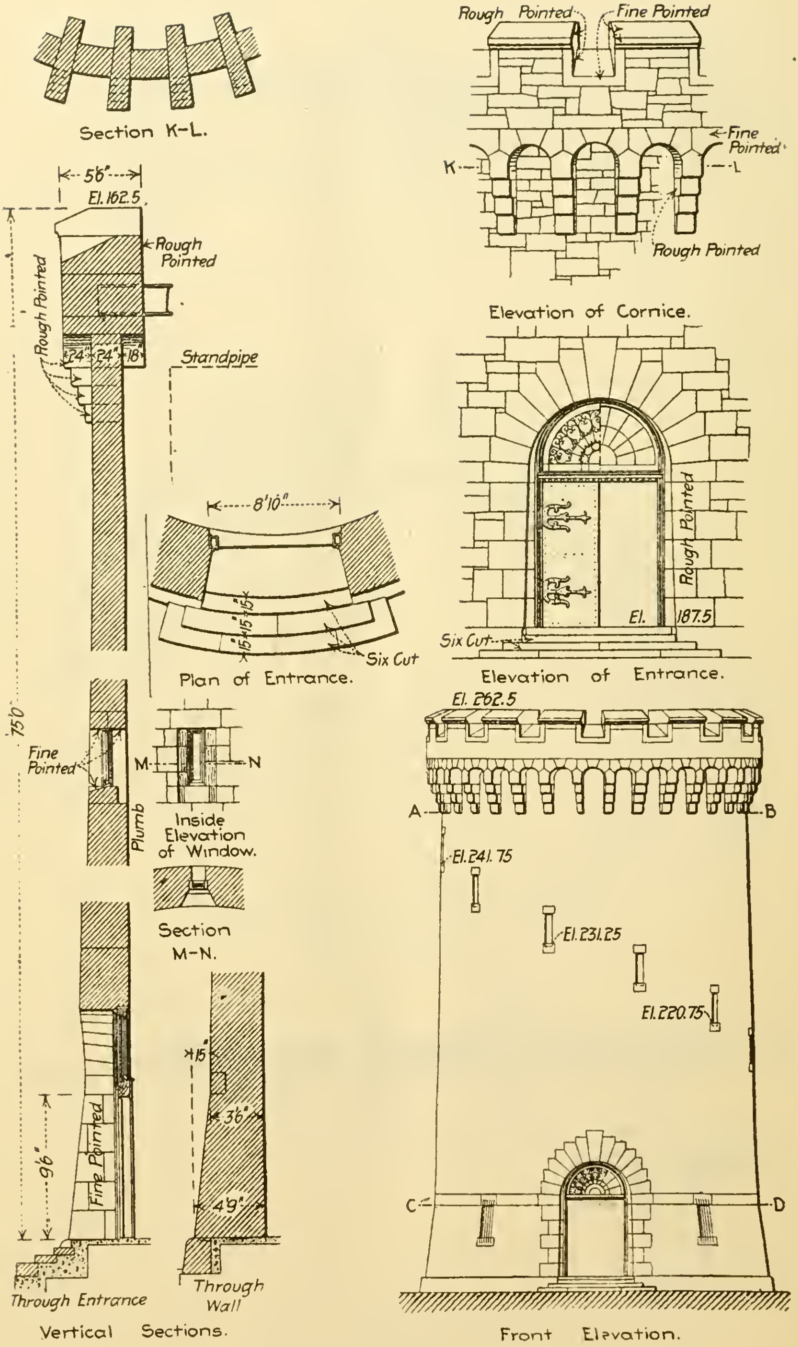


FIG. 7. MASONRY TOWER.

the stone, since it allowed the joints to be cut as though the arch were in a plane wall, after which the faces could be cut to curve and batter. Considerable difficulty was encountered, however, in cutting these stones, and it was found best to rough them out as nearly as possible, try them temporarily in their places in the arch, resting on the centering, and finally trim them to proper shape. This method would have been unnecessary if the foreman stonecutter had given proper attention to the work, as the plans were perfectly clear in this respect.

The contractor commenced work on May 27. Two forty-foot boom derricks, operated by hand, were set up and used until the wall was about ten feet high. They were first set up on the south side of the tower, moved around to the north side as the work progressed, and finally removed altogether. Between the outside of the standpipe and the inside of the masonry wall is a space three feet three inches wide, in which will finally be placed a circular stairway leading to the observation roof. In this space the contractor at once began to erect a wooden staging and working platforms. Pairs of uprights three feet three inches outside to outside, with one side resting against the plates, were spaced about six feet apart around the tank. These were of three by four spruce stock except at two places directly opposite each other, where they were of hard pine, those next the tank being six by eight and those outside being four by six spruce. These uprights were thoroughly cross braced, and when the staging was completed two wire ropes were passed around the tower outside the inner row of uprights and, when tightened by turnbuckles, bound the staging firmly to the tank. When the staging was finished two pairs of four by twelve hard pine timbers, six feet on centers and thirty feet long, trussed with one and one-fourth inch steel rods, were placed across the top of the tank, resting partly on the sides of the tank and partly on the six by eight hard pine uprights and other portions of the staging. On these trusses and on other timbers resting on the top of the tank, a plank platform was built and covered with sail-cloth to prevent dirt and stones from falling into the tank. Until the wall was built nearly to the top of the tower the tank was kept almost full of water, to afford as much stability as possible. On top of the platform between the trusses and over the center of the tank and tower the derrick was placed with which the larger part of the stone was handled. This derrick had a thirty-foot boom and a twenty-foot mast. It was held in place by six five-eighths-inch wire

guys, anchored to fourteen by fourteen inch hard-pine uprights and deadmen from three hundred to four hundred feet distant from the tower.

This derrick was operated by a twelve horse-power double-drum engine, set on the ground about sixty feet south of the tower. Single iron blocks ten inches in diameter with one-half inch wire falls were used until the big stones for the top were to be raised, when a two-part block was substituted on the boom. This derrick was pivoted so that it could swing all about the tower, but, on account of the leaders to the engine, could not make a second revolution in the same direction. The staging and partially completed wall are shown on Plate V, Fig. 1.

The following description, partially abstracted from the specifications, gives a general idea of the character of the work: —

The cement, sand, and concrete conformed to the requirements of first-class work. Except as otherwise stated, uncoursed rubble masonry laid in natural cement mortar, mixed in the proportion of 1 part cement to 2 parts sand by measure, was used for the wall of the tower. The stones in this portion of the work were of sound, clean, Quincy granite "grout," from which thin edges and large projections had been removed. Headers constituted about one fourth the area of the outside face, and were of sufficient size to secure a strong bond with the rest of the masonry. The exterior of the tower, the interior above the roof, and a band about eight feet wide following the wind of the stairs were laid to such a face that no stone projects more than two inches beyond the neat lines. In the remainder of the work no stone projects nearer to the tank than three feet. In the rubble work the stones were all roughly dressed to lay with joints on the face averaging three fourths of an inch, great care being taken to break joints in the several courses. Very few stones were used having a face area less than one square foot, and the least depth of bed for the face stones was limited to six inches, the length of bed being twice the rise for stones having a rise of less than twelve inches. The steps at the entrance, the base course, voussoirs of all arches, the quoins of the entrance, the sills and lintels of all windows, the belt course at the top of the lower windows, the corbels carrying the cornice arches, the sills of the embrasures, the caps of the merlons, and the band under the caps were of best quality Quincy or Rockport granite. The bed joints of these stones were dressed for six inches from the face and laid with a

Fig. 1. — Inside of Completed Reservoir.

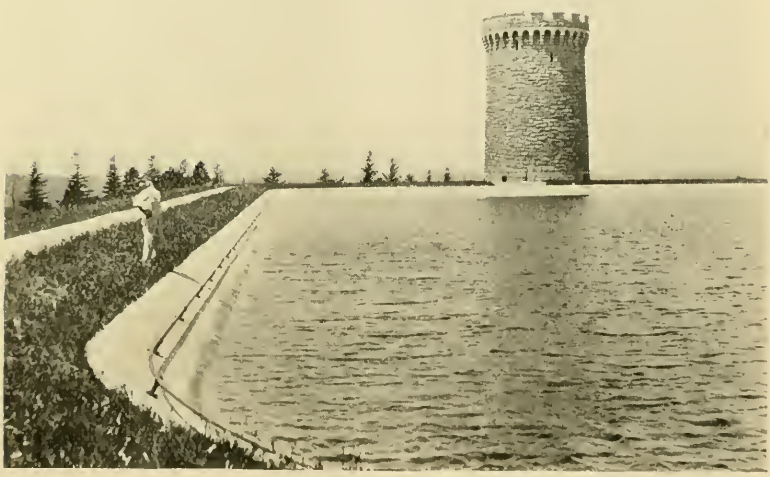


Fig. 2. — Reservoir and Masonry Water Tower.

joint not exceeding one-half inch for this distance, and a limit of three inches for the remainder of the joint, except in the case of the radial joints of the voussoirs, where no portion of the joint exceeded one inch in thickness.

The dimension stones were laid with the same quality of mortar as used in other parts of the work. The exposed faces of the steps, the washes and tops of the sills and bottoms of the lintels of the large windows were six-cut, the faces of the sills and lintels of the small windows rock-faced, and the remainder of the dimension stone either rough or fine pointed. The roof framing consists of steel beams, channels, and plates fitted and framed together. At the main entrance there are boiler iron doors stiffened with angle irons, studded with rivets, and hung on forged hinges. The stair carriages consist of five-sixteenths by eight inch plates and three by five inch angles thoroughly braced and anchored to the wall. The treads and landings are to be cast and have suitable pattern work on the top surface. The railings and stanchions are to be of wrought-iron pipe. All iron-work is to be of the best quality, and the workmanship first-class in every respect.

An eight-inch overflow pipe from the top of the standpipe and a three-inch drain pipe from the roof, both of wrought iron, are carried down to the vault in the foundation in a chase left in the wall for this purpose. The lower windows and transom over the door are to be protected with suitable wrought-iron grilles.

The roof is to be composed of eight-inch terra-cotta flat arches, "end construction," covered with Portland cement concrete mixed 1 part cement, 2 parts sand, and 5 parts fine gravel. On top of the concrete is to be placed a one-fourth inch coat of neat Portland cement mortar, thoroughly troweled and floated to make a water-tight surface which shall pitch evenly to drainage points. Over this plastering a water-proof covering, two feet six inches wide, consisting of four layers of twenty-five pound saturated felt lapped three inches and cemented with hot pitch, is to be laid around the roof next the wall. This is to be flashed with five-pound lead let into the joints in the wall. On top of the plaster surface and water-proof layer is to be spread a thin layer of clean cinders and on top of this a concrete layer about three inches thick, finished with a granolithic wearing surface sloping to a drain in the center of the roof. The intention is, that if the granolithic surface of the roof cracks, water will not lodge under and in the concrete, and, then freezing, do serious damage ; but will filter

through the cinder layer and thence into the tank. This, of course, will be only in very small quantities, as the bulk of the water falling on the roof will be discharged by the drain outside the tank.

The upper portion of the stairs and the landing on the roof are to be covered with a wooden hood, the exposed portions of which are to be of best quality hard pine. Iron brackets about six feet apart have been let into the stonework on the inside of the tower about three feet below the top of the standpipe to carry a platform to give access to all parts of the top of the tank. In the roof two hatchways with iron frames and covers are placed, to give light and facilitate entrance for work inside the tank.

On account of delay in receiving the cut stone, the progress has been very slow. However, with the exception of the steps at the entrance and the cleaning and pointing, this portion of the work is now finished. The completed tower is shown in Plate VI, Fig. 2, and the detail of the entrance in Plate V, Fig. 2.

The average force employed per day during the time when the stonework was well under way was, one foreman, one engineer, five stonecutters, one blacksmith, two tag men, three tenders, two drillers, and nine masons; — in all, twenty-four men.

The dimension stone was supposed to be delivered on the work ready to be placed, but all the entrance arch stones and many of the others were brought to the work in the rough and cut on the ground. Beside these many of the other stones required some trimming, and some had to be entirely recut.

After freezing weather came, Portland cement was substituted for the natural cement previously used, and the proportion changed to 1 part cement and 3 parts sand. At this time also all materials for the mortar were heated, and the freshly laid masonry protected as well as possible.

COST OF WORK.

The several tables show the cost of the work and the quantities of materials used and handled except on the masonry tower, which is not yet completed. All data of cost except those in Table No. 9 are *actual* costs to the contractor, estimated from the force accounts and notes kept by employees of the Metropolitan Water and Sewerage Board. Table No. 9 is compiled from payments made by the Commonwealth on account of the work herein described.

All elevations given either in the text or on the plates are referred to Boston City base, which is approximately the elevation of mean low water in Boston Harbor.

WATER WORKS STATISTICS FOR THE YEAR 1901, IN FORM ADOPTED BY THE NEW ENGLAND WATER WORKS ASSOCIATION.

COMPILED BY CHARLES W. SHERMAN, EDITOR, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

The following tables of statistics contain more or less complete statistics for forty water works, which have used, more or less closely, the form adopted by the Association for summarizing statistics. Some of these works report under very few of the headings of the summary.

The Editor has made no attempt to compile statistics from water-works reports which do not include at least a partial summary.

The report of the Committee on Uniform Statistics, containing the form as endorsed for use in the 1901 reports, is printed on page 51 of this volume of the JOURNAL (March, 1902).

Previous compilations of statistics may be found in the JOURNAL, as follows: —

Statistics for	*Reference to Journal.*		
1886	Vol. I,	No. 4,	p. 29
1887	Vol. II,	No. 4,	p. 28
1888 to 1892 inclusive	Vol. VII,		p. 225
1893	Vol. IX,		p. 127
1894	Vol. X,		p. 131
1895–96	Vol. XII,		p. 273
1897–99	Vol. XV,		p. 65
1900	Vol. XV,		p. 367

1901. — TABLE I. — GENERAL AND PUMPING STATISTICS.

Number.	Name of City or Town.	Date of Construction of Works.	By Whom Owned.	Source of Supply.	Mode of Supply.	1. Builders of Pumping Machinery.	2. — Description of Fuel Used. a. Kind.	b. Brand of Coal.	c. Av. Price per Gross Ton.	d. Per Cent. of Ash.	e. Wood. Price per Cord.
1	Atlantic City, N. J.	1882, 1888	City.	Driven and Artesian Wells and Absecon Creek.	Pumping.	Worthington, Gordon-Maxwell, D'Auria, Smith-Vaile.	Bitu. Coal.	Lilly and Eureka.	$3 50	6.	. .
							Anth. Coal.	Seneca, Lyken.	3 74	9.2	. .
2	Attleboro, Mass. .	1873	Town.	Well near Seven Mile River.	Pumping.	Deane, Barr.	Bitu. Coal.	Georges Cr.	. .	. .	. .
3	Bay City, Mich. .	1872	City.	Saginaw Bay.	Pumping.	Holly.	Bitu. Coal.	Bay Co.	1 42	. .	$0 50
4	Billerica, Mass. . .	1898	Town.	Driven Wells.	Pumping.	Barr.	Bitu. Coal.	Georges Cr.	4 70	. .	. .
5	Brockton, Mass. .	1880	City.	Salisbury Brook.	Pumping.	Worthington, Barr.	Bitu. Coal.	Georges Cr.	5 14	8.8	. .
6	Burlington, Vt. .	1867	City.	Lake Champlain.	Pumping.	Worthington.	Bitu. Coal.	Clearfield.	4 05	. .	. .
7	Cambridge, Mass. .	1855	City.	Stony Brook, Hobbs Brook, Fresh Pond.	Pumping.	Leavitt, Worthington, Blake.	Bitu. Coal.	Cumberl'd.	4 08	. .	. .
8	Chelsea, Mass. . .	1867	City.	Metropolitan W. W.	. . .	. . .	. . .	. . .	. .	. .	. .
9	Concord, N. H. .	1872	City.	Penacook Lake.	Gravity and Pumping.	. . .	Bitu. Coal.	Pocahontas.	. .	. .	. .
10	Fall River, Mass. .	1874	City.	Watuppa Lake.	Pumping.	Worthington, Davidson.	Bitu. Coal.	Georges Cr.	. .	. .	. .
11	Fitchburg, Mass. .	1873	City.	Storage Reservoirs.	Gravity.	. . .	. . .	. . .	. .	. .	. .
12	Freeport, Me. . .	1891	Private Owner.	Brook and Springs.	Pumping.	Deane.	Bitu. Coal.	New River.	3 50	. .	2 50
13	Holyoke, Mass. . .	1873	City.	Lakes and Streams.	Gravity.	. . .	. . .	. . .	. .	. .	. .
14	Lowell, Mass. . .	1870	City.	Driven Wells.	Pumping.	Morris, Worthington, Deane, Knowles.	Bitu. Coal.	Cumberl'd.	4 70	. .	. .
15	Lynn, Mass. . . .	1870	City.	Brooks and Saugus River.	Pumping.	Morris, Loretz.	Bitu. Coal.	Georges Cr.	. .	. .	. .

16	Maynard, Mass.	1889	Town.	White Pond.	Pumping.	Blake.	Bitu. Coal.	Georges Cr.	$4 65	20.	. .
17	Metropolitan Water Works, Mass.	1848, 1872, 1895	State of Massachusetts.	Lake Cochituate, Sudbury River, Nashua River.	Pumping.	*Chestnut*	*Hill High*	*Service*	*Stati*	*on.*	
						Holly, Quintard Iron Works, Allis.	Bitu. Coal. Anth. Coal.	Georges Creek. Loyal Hanna. Screen'gs.	4 29	9.2	. .
						Chestnut	*Hill Low*	*Service*	*Stati*	*on.*	
						Holly.	Bitu. Coal.	Loyal Hanna.	4 44	8.9	. .
						Spot	*Pond*	*Station.*			
						Blake, Holly.	Bitu. Coal. Anth. Coal.	Georges Cr. Screenings.	4 41	9.7	. .
18	Middleboro, Mass.	1885	Fire Dist.	Well.	Pumping.	Deane.	Bitu. Coal.	Pocahontas, Cumberland.	4 70	. .	. .
19	Minneapolis, Minn.	1868	City.	Mississippi River.	Pumping.	Hardenburg, Waters, Pray, Strothman, Worthington, Holly.	Sawdust, Edgings, etc., and some Coal.	. . .	. .	. .	(1)
20	New Bedford, Mass.	1866, 1895	City.	Quittacas Ponds.	Pumping.	Quintard, Worthington, Dickson Mfg. Co.	Bitu. Coal.	Pocahontas.	4 95	7.	$4 00
21	New London, Conn.	1872	City.	Lake Konomoc.	Gravity.	. . .	. . .	. . .	. .	. .	. .
22	Newton, Mass. . .	1876	City.	Collecting Gallery.	Pumping.	Blake, Worthington.	Bitu. Coal.	Georges Cr.	4 37	8.	6 00
23	Norwich, Conn.	1868	City.	. . .	Gravity.	. . .	. . .	. . .	. .	. .	. .
24	Oberlin, Ohio	1887	Village.	East Branch of Vermilion River.	Pumping.	Deane.	Semi-Bitu.	Pocahontas.	3 70	. .	. .
25	Plymouth, Mass.	1855	Town.	Great and Little South Ponds, Lout Pond.	Gravity and Pumping.	Worthington.	Bitu. Coal.	Various.	5 00	. .	. .

[1] Sawdust, $4.00 per million gallons pumped.

1901.—TABLE 1, *Continued.*—GENERAL AND PUMPING STATISTICS.

Number.	Name of City or Town.	Date of Construction of Works.	By Whom Owned.	Source of Supply.	Mode of Supply.	1 Builders of Pumping Machinery.	2.—Description of Fuel Used. *a* Kind.	*b* Brand of Coal.	*c* Av. Price per Gross Ton.	*d* Per Cent. of Ash.	*e* Wood. Price per Cord.
26	Providence, R. I. .	1870	City.	Pawtuxet River.	Pumping.	Worthington,	Bitu. Coal.	New River, Georges Cr.	4 20	9.9	$4 50
						Corliss,	Bitu. Coal.	New River, Georges Cr.	4 12	10.4	4 50
						Holly,	Anth. Coal.	Reading, Egg.	5 04	16.4	4 00
						Nagle,	Anth. Coal.	Reading, Egg.	5 04	15.4	4 00
27	Quincy, Mass. . .	. .	City.	Metropolitan W. W.	. . .	. . .	. . .	. . .	. .	. .	. .
28	Reading, Mass. . .	1890	Town.	Filter Gallery.	Pumping.	Blake.	Bitu. Coal.	Georges Cr.	5 10	. .	. .
29	Reading, Pa. . .	1819	City.	Creeks and Springs.	24.8% Pump'ng 75.2% Gravity.	Worthington.	Bitu. and An. Coal.	. . .	2 59	14.5	3 25
30	Schenectady, N. Y.	1894	City.	Collecting Gallery.	Pumping.	Dean.	. . .	. . .	. .	. .	. .
31	Somerville, Mass. .	1868	City.	Metropolitan W. W.	. . .	. . .	. . .	. . .	. .	. .	. .
32	Springfield, Mass. .	1864 1873 1890	City.	Reservoirs.	Gravity.	. . .	. . .	. . .	. .	. .	. .
33	Taunton, Mass. .	1876	City.	Elder's and Assawompsett Pds.	Pumping.	Holly, Allis.	Bitu. Coal.	Cumberl'd.	4 25 4 75	12.3 9.5	. .
34	Waltham, Mass. .	1872	City.	Filter Basin near Charles River.	Pumping.	Barr, Worthington.	Bitu. Coal.	Georges Cr.	4 78	11.	. .
35	Ware, Mass. . . .	1886	Town.	Wells.	Pumping.	Dean.	Bitu. Coal.	Georges Cr.	4 83	. .	5 00
36	Wellesley, Mass. .	1884	Town.	Wells.	Pumping.	Blake.	Bitu. Coal.	Puritan.	4 68	9.9	3 50
37	Whitman, Mass. .	1883	Town.	Well.	Pumping.	Blake, Worthington.	. . .	. . .	. .	. .	. .
38	Winchendon, Mass.	1896	Town.	Well.	Pumping.	Blake.	Bitu. Coal.	Cumberl'd.	5 52	9.	. .

39	Woburn, Mass.	1872	City.	Filter Gallery near Horn Pond.	Pumping.	Worthington, Blake.	Bitn. Coal.	Elk Garden, Georges Creek.	$4 41	9.	. .
40	Yonkers, N. Y.	1874	City.	Streams and Tubular Wells.	Pumping.	Wright, Worthington, Camden.	Bitn. Coal.	Georges Cr.	3 85	. .	$10 00

1901.—TABLE 1, *Concluded*.—PUMPING STATISTICS.

Number.	3 Coal Consumed for the Year. (Lbs.)	4 Lbs. of Wood ÷ 3 = Equivalent Coal.	4a Amount of Other Fuel Used.	5 Total Equivalent Coal Consumed for the Year. (Lbs.) (3) + (4).	6 Total Pumpage for the Year in Gallons.	7 Average Static Head against which Pumps Work. (Feet.)	8 Average Dynamic Head against which Pumps Work. (Feet.)	9 Number of Gallons Pumped per Lb. of Equivalent Coal.	10 Duty in Foot-pounds per 100 Pounds of Coal. No Deductions.	11 Cost per Million Gallons pumped into Reservoir, figured on Pumping Station Expenses.	12 Cost per Million Gallons raised 1 Foot high, figured on Pumping Station Expenses.	13 Cost per Million Gallons pumped into Reservoir, figured on Total Maintenance (CC).	14 Cost per Million Gallons raised 1 Foot high, figured on Total Maintenance (CC).
1	3 401 615	5 000	. .	3 406 615	1 094 651 552	93	126 7	321	33 945 400	$ 8 81	$0 07	$ 82 57	$0 65
	1 276 978	3 000	. .	1 279 978	151 040 127	123 3	123 3	118	12 129 300	31 19	0 25		
2	498 200	. .	. .	. . .	147 946 520	. .	188 / 225	297	55 600 000	. . .	. . .	. . .	. . .
3	4 644 900	3 667	. .	4 648 567	1 082 691 511	. .	113	233	21 949 353	6 91	0 061	32 59	0 288
4	231 035	. .	. .	. . .	21 946 359[1]	275	317 5	95	25 108 771	73 29	0 23	273 45	0 86
5	445 508	100	. .	445 608	443 938 118[1]	38	43	996	35 727 610	6 66	0 154	107 89	2 51
6	. . .	. .	. .	. . .	304 685 775	289	316	. .	. . .	28 17	0 089	119 60	0 378
7	3 619 340	500	. .	3 619 840	2 785 156 440	158	194 4	769	124 770 490	5 40	0 028	28 45	0 116
9	301 716	. .	. .	. . .	149 371 035	. .	. .	495	. . .	. . .	. . .	. . .	. . .
10	. . .	. .	. .	. . .	1 320 839 810	. .	185 8	323	. . .	9 71	. . .	97 27	. . .
12	153 800	6 000	. .	159 800	18 045 000[1]	160	180	118	150 683 605	51 40	0 32	130 55	0 82
14	3 774 196[2]	2 400[2]	. .	3 767 596[2]	2 178 818 435[2]	156[2]	163 6[2]	577[2]	78 712 429[2]	8 11[2]	0 05[2]	. . .	. . .
15	40 400	. .	. .	. . .	19 582 505	. .	165 5	484	66 899 779	7 02	0 042	85 10	0 509
	2 625 400	. .	. .	. . .	1 624 680 750	. .	157 5	618	81 265 994				
16	299 778	. .	. .	299 778	54 884 545[1]	190	212	183	31 240 547	. . .	. . .	. . .	. . .
17	*Chestnut*	*Hill*	*High*	*Service*	*Station.*								
a	499 756	. .	. .	. . .	202 470 000	. .	124 3	608	65 760 000	10 63	0 086	. . .	. . .
b	310 069	. .	. .	. . .	204 510 000	. .	48 1	1 077	45 090 000	9 52	0 198	. . .	. . .
c	953 488	. .	. .	. . .	1 016 570 000	. .	125 3	1 102	118 600 000	4 36	0 035	. . .	. . .
d	482 009	. .	. .	. . .	645 580 000	. .	67 8	1 479	86 090 000	3 76	0 055	. . .	. . .
e	6 346 061	. .	. .	. . .	8 584 110 000	. .	126 3	1 353	144 450 000	3 17	0 025	. . .	. . .
	Chestnut	*Hill*	*Low*	*Service*	*Station.*								
f	8 528 670	. .	. .	. . .	26 354 400 000	. .	48 4	3 090	126 420 000	1 50	0 031	. . .	. . .
		Spot	*Pond*	*Station.*									
g	344 975	. .	. .	. . .	351 890 000	. .	114 5	1 020	99 320 000	5 45	0 048	. . .	. . .
h	2 076 021	. .	. .	. . .	2 414 530 000	. .	119 5	1 163	117 700 000	4 75	0 040	. . .	. . .

18	536 970	. .	. .	. . .	81 884 000[1]	182	203	152	25 796 680	$31 95	$0 157	$ 89 25	$0 44
19	1 435 716	. .	22 435	. . .	6 591 613 020	. .	. .	. .	{ 72 337 614 } { 74 842 026 }	. . .	. . .	. . .	. . .
	Little Quittacas Station.												
20	2 557 950	33	. .	2 557 983	2 086 593 318[4]	166 3	189 5	816	128 932 159	5 99	0 032	53 33	0 281
	Purchase Street Station.												
	132 050	33	. .	132 083	45 275 272[2]	184 4	192	343	54 899 943				
22	1 720 800	6 000	. .	1 726 800	673 803 875[1]	234	254	390	82 660 000	13 60	0 055	169 72	0 67
24	303 000	. .	. .	. . .	40 374 000[1]	80	80	133	8 890 000	38 90	0 48	111 30	1 36
25	. . .	. .	. .	407 430	193 430 160	65	66	483	26 132 139	13 88	0 21	61 08	0 925
26	5 690 300	833	. .	5 691 133	3 891 304 283[4]	171 5	176 9	684	100 888 000	4 70	0 027	. . .	. . .
	280 500	4 750	. .	285 250	165 074 474[4]	171 5	177	579	85 441 200	(low serv.)			
	775 913	1 376	. .	777 289	176 290 901[4]	112 0	126 6	613	64 702 900	15 25	0 111	. . .	. . .
	121 159	206	. .	121 365	67 525 560[4]	111 1	112 6	556	52 253 800	(high serv.)			
28	481 469	. .	. .	. . .	57 479 577[1]	219	240	119	23 892 917	47 00	0 196	265 95	1 10
29	2 123 310	1 200	. .	2 124 510	704 993 037[1]	212 8	252	331	69 741 717	8 82	0 035	92 71	0 368
33	1 122 019	. .	. .	1 122 019	631 214 244	. .	67 5	558	31 655 803	9 92	14 70	89 55	1 38
	403 000	. .	. .	403 000	504 135 478	. .	. .	. .	. . .				
34	1 481 840	. .	. .	1 481 840	836 407 890[1]	164	180	. .	85 204 300	10 15	0 056	49 87	0 277
35	578 710	900	. .	579 610	116 793 885[1]	221	244	201	41 005 311	17 23	0 07	58 26	0 238
36	486 844	387	. .	487 231	88 975 417[1]	260	286	182	42 639 732	25 80	0 09	183 62	0 656
38	190 600	. .	. .	190 600	31 368 800[4]	240	280	198	45 660 004	25 28	0 093	198 56	0 709
39	1 522 200	. .	. .	1 522 200	426 638 100[1]	200	216	280	50 490 273	14 89	0 069	27 25	0 126
40	4 176 325	. .	. .	. . .	1 272 378 811	185	. .	304	. . .	10 67	. . .	. . .	. . .

[1] Without allowance for slip. [2] Station No. 1 only. [3] Cords sawdust (1 cord assumed = 585.8 lbs. coal). [4] With allowance for slip.

a Engines Nos. 1 and 2. *b* Engines Nos. 1 and 2 (low service). *c* Engine No. 3. *d* Engine No. 3 (low service). *e* Engine No. 4. *f* Engines Nos. 5, 6, and 7. *g* Engine No. 8. *h* Engine No. 9.

1901.—TABLE 2.—FINANCIAL STATISTICS.—MAINTENANCE.

Number.	Name of City or Town.	Balance from Previous Year.	Receipts from Consumers.				
			A	B	C	D	E
			Fixture Rates.	Meter Rates.	Net Receipts for Water.	Miscellaneous Receipts.	Total Receipts from Consumers.
1	Atlantic City, N. J.	$ 2 794 19	. . .	. . .	$ 94 327 57	. . .	. . .
2	Attleboro, Mass.	. . .	. . .	. . .	27 325 34	$ 87 50	. . .
3	Bay City, Mich.	. . .	$ 9 639 43	$ 14 426 31	24 065 74	809 91	$ 24 875 65
4	Billerica, Mass.	. . .	1 357 61	1 427 32	2 784 93	48 21	2 833 14
5	Brockton, Mass.	. . .	8 154 02	62 209 14	70 363 16	6 707 39	77 070 55
6	Burlington, Vt.	. . .	9 001 93	38 829 60	47 831 53	1 354 21	49 185 74
7	Cambridge, Mass.	. . .	213 493 04	109 380 25	322 873 29	. . .	329 224 47
8	Chelsea, Mass.	. . .	62 240 46	19 709 60	81 950 06	2 618 33	84 568 39
9	Concord, N. H.	. . .	30 240 99	31 762 73	62 172 56	155 42	62 327 98
10	Fall River, Mass.	30 512 97	3 946 07	159 057 74	. . .	. . .	168 034 17
11	Fitchburg, Mass.	. . .	22 357 29	43 170 61	. . .	. . .	69 035 38
12	Freeport, Me.	. . .	2 000 00	0	2 000 00	. . .	2 000 00
13	Holyoke, Mass.	25 584 08	71 603 37	15 767 70	87 371 07	. . .	. . .
15	Lynn, Mass.	. . .	. . .	. . .	193 331 57	. . .	. . .
16	Maynard, Mass.	3 110 33	4 560 42	1 807 33	6 367 75	626 55	6 994 30
18	Middleboro, Mass.	2 930 09	3 662 19	7 174 03	10 836 22	572 63	11 408 85
20	New Bedford, Mass.	5 795 02	73 192 32	34 391 32	107 583 64	580 26	108 163 90

21	New London, Conn. . . .	. . .	. . .	. . .	$ 51 415 38	. . .	. . .
22	Newton, Mass.	. . .	$ 3 808 04	$ 99 828 85	103 636 89	$ 10 369 43	$ 114 006 32
23	Norwich, Conn.	. . .	42 604 58	10 744 66	53 349 24	2 172 24	. . .
24	Oberlin, Ohio	. . .	886 85	5 120 00	6 006 85	111 35	6 118 20
25	Plymouth, Mass.	. . .	. . .	. . .	23 025 02	1 115 99	24 141 01
27	Quincy, Mass.	. . .	. . .	. . .	69 300 00	. . .	69 300 00
28	Reading, Mass.	. . .	. . .	9 078 86	9 078 86	273 27	9 352 13
29	Reading, Pa.	. . .	127 265 57	39 057 99	166 323 56	920 66	167 244 22
31	Somerville, Mass.	. . .	161 201 05	51 116 54	212 317 59	1 815 77	214 133 36
32	Springfield, Mass.	$11 686 38	148 476 70	70 338 35	218 815 05	{ 736 00 / 19 008 46 }	238 559 51
33	Taunton, Mass.	. . .	. . .	. . .	58 427 84	396 58	58 824 42
34	Waltham, Mass.	4 043 60	60 572 54	8 698 32	69 270 86	1 328 76	70 599 62
36	Wellesley, Mass.	. . .	. . .	13 075 17	13 075 17	526 34	13 601 51
38	Winchendon, Mass.	372 23	13 26	4 434 82	4 448 08	47 77	4 495 85
39	Woburn, Mass.	. . .	34 766 45	6 114 33	40 880 78	884 09	41 764 87
40	Yonkers, N. Y.	14 184 91	. . .	. . .	117 145 68	8 194 46	. . .

1901. — TABLE 2, *Continued.* — FINANCIAL STATISTICS. — MAINTENANCE.

Number.	Receipts from Public Funds.							Expenditures.				
	F	G	H	I	J		K	AA	BB	CC	DD	K
	Hydrants.	Fountains.	Street Watering.	Public Buildings.	General Appropriation or Miscellaneous.	Total from Public Funds.	Gross Receipts from All Sources.	Management and Repairs.	Interest on Bonds.	Total Maintenance for the Year.	Balance.	Total.
1	. . .	. . .	. . .	. . .	. . .	. . .	$142 824 07	. . .	$ 44 015 00	. . .	$ 9 696 93	. . .
2	. . .	. . .	. . .	. . .	$ 5 000 00	. . .	32 412 84	. . .	13 192 50	. . .	3 01	. . .
3	. . .	. . .	. . .	. . .	21 590 00	$21 590 00	46 465 65	$13 699 72	21 590 00	$ 35 289 72	11 175 93	$ 46 465 65
4	$2 300 00	. . .	. . .	$119 96	749 15	3 169 11	6 002 25	2 402 25	3 600 00	6 002 25	. . .	6 002 25
5	3 000 00	. . .	$1 000 00	. . .	. . .	4 000 00	81 070 55	16 200 50	31 697 50	47 898 00	33 172 55	81 070 55
6		Included	in Receip	ts—Meter	Rates.		45 185 74	26 440 53	9 920 00	36 360 53	6 421 50[1] 6 403 71[2]	49 185 74
7	. . .	. . .	. . .	. . .	. . .	. . .	329 224 47	79 762 67	119 703 75[2] 127 109 00	326 575 42	2 649 05	329 224 47
8	2 002 50	$7 50	1 703 82	710 00	. . .	4 423 82	88 992 21	29 570 40[3] 14 941 94	12 000 00	. . .	5 410 00[2] 4 868 17[1] 22 201 70[5]	88 992 21
9	. . .	. . .	. . .	. . .	. . .	. . .	62 327 98	. . .	25 700 00	. . .	. . .	. . .
10	. . .	. . .	. . .	. . .	. . .	. . .	198 547 14	46 142 36	93 340 00	139 482 36	59 064 78	198 547 14
12	1 000 00	. . .	. . .	. . .	. . .	1 000 00	3 000 00	1 100 00	1 250 00	2 350 00	650 00	3 000 00
13	. . .	. . .	. . .	. . .	. . .	. . .	121 838 84	21 530 28	12 000 00	33 530 28	?	121 838 84
15	. . .	. . .	. . .	. . .	. . .	. . .	201 555 29	76 862 00	72 596 24	149 458 24	52 097 05[2]	201 555 29
16	2 000 00	6 60	. . .	. . .	48 82	2 055 42	12 160 05	3 400 86	5 000 00	2 389 23	1 369 96	12 160 05
18	. . .	. . .	. . .	. . .	. . .	1 500 00	15 838 94	5 008 06	2 300 00	7 308 06	3 000 00[2] 1 538 67[1] 3 992 21	15 838 94
20		12 000 00			72 580 00	84 580 00	198 538 92	36 107 59	77 580 00	113 687 59	30 000 00[4] 28 000 00[2] 26 851 33	198 538 92

21	$11 000 00	$ 150 00	$4 000 00	$ 400 00	. . .	. . .	$ 67 045 38	$ 6 877 90	$14 915 00	$ 21 792 90	$ 45 252 48	$ 67 045 38
22	14 250 00	828 00	3 000 00	2 207 00	. . .	$20 285 00	134 291 32	16 861 09	97 500 00	114 361 09	19 930 23	134 291 32
23	0	103 00	200 00	306 00	0	609 00	56 130 48	10 171 72	12 750 00	22 921 72	33 208 76	56 130 48
24	. . .	. . .	. . .	. . .	$4 010 01	4 010 01	10 128 21	2 846 00	1 647 54	4 493 54	5 634 67	10 128 21
25	. . .	. . .	. . .	. . .	. . .	0	24 141 01	11 374 17	4 527 60	15 901 77	8 239 24	24 141 01
27	. . .	. . .	. . .	. . .	. . .	. . .	69 300 00	{ 10 000 00 24 000 00[3] }	29 000 00	63 000 00	6 300 00	69 300 00
28	4 200 00	300 00	300 00	. . .	1 000 00	{ 155 07[6] 5 800 00 }	15 307 20	6 567 20	8 740 00	15 307 20	. . .	15 307 20
29	. . .	. . .	. . .	. . .	. . .	0	167 244 22	38 753 99	{ 19 104 00 7 500 00[2] }	65 357 99	101 886 23	167 244 22
31	. . .	. . .	. . .	. . .	. . .	. . .	214 133 36	{ 33 114 56 56 816 76[3] }	8 270 00 32 000 00[4] }	130 201 32	{ 18 892 07[1] 65 039 97[5] }	214 133 36
32	19 280 00	2 032 26	0	11 484 87	0	32 797 13	271 356 64	{ 4 532 69[7] 22 613 29 }	87 250 00	114 395 98	?	?
33	0	2 276 32	0	505 75	2 054 91	. . .	63 661 40	23 640 70	32 868 00	56 508 70	7 152 00[2]	63 661 40
34	. . .	. . .	. . .	. . .	. . .	. . .	74 643 22	24 665 42	17 045 00	41 710 42	{ 25 500 00[2] 7 432 80 }	. . .
36	———	5 000 00	———	133 72	. . .	5 133 72	18 735 23	5 932 22	11 080 00	17 012 22	1 723 01	18 735 23
38	3 800 00	255 00	153 60	. . .	. . .	4 208 60	9 076 68	2 428 73	3 800 00	6 228 73	2 847 95	9 076 68
39	. . .	250 00	250 00	550 00	. . .	1 050 00	42 814 87	11 627 99	4 774 00	16 401 99	26 412 88[2]	42 814 87
40	23 880 00	. . .	. . .	. . .	. . .	. . .	163 405 05	54 600 85	77 825 00	. . .	30 979 20[2]	163 405 05

[1] To Construction. [2] Sinking Fund. [3] Metropolitan Water Works Assessment. [4] Bonds Paid. [5] To City Treasury.
[6] From Construction Account. [7] Special.

1901.—TABLE 2, *Continued.*—FINANCIAL STATISTICS.—CONSTRUCTION.

Number.	Name of City or Town.	CONSTRUCTION RECEIPTS.					
		Q	R	S	T	U	V
		Balance from Previous Year.	Bonds Issued.	Appropriations from Tax Levy.	Transferred from Maintenance Account.	Other Sources.	Total.
1	Atlantic City, N. J.	. . .	. . .	. . .	$19 529 39	$ 1 299 52	$20 828 91
2	Attleboro, Mass.	. . .	$20 000 00	. . .	. . .	1 086 00	21 086 00
3	Bay City, Mich.	$11 235 21	. . .	. . .	11 175 93	774 60	23 185 74
4	Billerica, Mass.	45 41	. . .	$396 70	. . .	. . .	442 11
5	Brockton, Mass.	4 111 46	28 000 00	. . .	. . .	3 588 11	35 699 57
6	Burlington, Vt.	. . .	. . .	. . .	6 421 50	. . .	6 421 50
7	Cambridge, Mass.	14 575 52	30 000 00	. . .	. . .	{ 1 530 00 91 39 }	46 196 91
8	Chelsea, Mass.	. . .	. . .	. . .	4 868 17	. . .	4 868 17
9	Concord, N. H.	. . .	. . .	. . .	. . .	. . .	. . .
10	Fall River, Mass.	. . .	20 000 00	. . .	. . .	. . .	20 000 00
13	Holyoke, Mass.	. . .	. . .	. . .	50 566 03	. . .	. . .
15	Lynn, Mass.	16 053 89	25 000 00	. . .	. . .	1 842 41	42 896 30
18	Middleboro, Mass.	. . .	. . .	. . .	1 538 67	1 001 07	2 539 74
20	New Bedford, Mass.	. . .	. . .	. . .	26 851 33	6 966 64	33 817 97
21	New London, Conn.	37 485 56	. . .	. . .	45 252 48	. . .	82 738 04
22	Newton, Mass.	. . .	14 285 23	. . .	. . .	45 013 08	59 298 31
24	Oberlin, Ohio	391 80	. . .	. . .	2 634 67	335 72	3 362 19

25	Plymouth, Mass.	. . .	$20 554 00	. . .	$ 1 599 24	$ 883 82	$ 23 037 06
27	Quincy, Mass.	. . .	30 000 00	. . .	. . .	3 000 00	33 000 00
28	Reading, Mass.	$ 48 93	6 835 83	$ 1 000 00	. . .	1 162 15	9 046 91
29	Reading, Pa.	54 315 97	. . .	. . .	101 886 23	6 253 31	162 455 51
31	Somerville, Mass.	. . .	. . .	. . .	18 892 07	313 52	19 205 59
32	Springfield, Mass.	0	. . .	. . .	12 703 70	1 165 10	13 868 80
33	Taunton, Mass.	38 343 51	. . .	15 000 00	. . .	8 250 27	61 593 78
34	Waltham, Mass.	5 590 49	6 000 00	. . .	. . .	4 101 84	15 692 33
36	Wellesley, Mass.	1 283 13	6 000 00	. . .	. . .	1 210 83	8 493 96
38	Winchendon, Mass.	. . .	. . .	5 500 00	642 38	. . .	6 142 38
39	Woburn, Mass.	10 98	. . .	650 00	. . .	397 81	1 058 79

1901.—TABLE 2, *Concluded.*—FINANCIAL STATISTICS.—CONSTRUCTION AND MISCELLANEOUS.

Number.	Construction Expenditures.							Miscellaneous.			
	FF	GG	HH	II	JJ	KK	V	W	X	Y	Z
	Extensions.			Special.	Total Cost of Construction for the Year.	Balance.	Total.	Net Cost of Works to Date.	Bonded Debt at Date.	Value of Sinking Fund at Date.	Average Rate of Interest, Per Cent.
	Mains.	Services.	Meters.								
1	$10 853 84	. . .	$ 9 975 07	. . .	$20 828 91	. . .	$20 828 91	$1 110 742 01	$1 085 500 00	$116 962 68	4.76
2	. . .	. . .	. . .	$ 4 062 07	15 429 12	$1 594 81	21 086 00	389 917 30	317 000 00	62 493 40	. . .
3	8 666 25	. . .	640 82	. . .	9 307 07	13 878 67	23 185 74	607 461 62	352 000 00	. . .	6
4	. . .	$ 390 90	. . .	51 21	442 11	. . .	442 11	92 147 98	90 000 00	5 062 75	5
5	24 716 64	2 267 65	3 320 21	. . .	30 304 50	5 395 07	35 699 57	943 515 56	805 000 00	360 695 76	4
6	5 292 74	1 128 76	. . .	. . .	6 421 50	. . .	6 421 50	474 461 23	248 000 00	abt. 34 000 00	4
7	12 379 90	. . .	13 971 98	5 846 83	32 198 71	13 998 20	46 196 91	5 702 428 23	3 332 100 00	757 731 54	3¾
8	4 115 17	624 00	129 00	. . .	4 868 17	. . .	4 868 17	488 203 69	300 000 00	66 377 60	4
9	21 228 53	1 563 23	1 972 08	. . .	. . .	. . .	. . .	873 196 76	650 000 00	. . .	. . .
10	. . .	. . .	. . .	. . .	20 000 00	. . .	20 000 00	1 964 456 00	1 940 000 00	635 648 14	4.8
11	. . .	. . .	. . .	. . .	. . .	. . .	. . .	429 775 26	548 000 00	118 224 74	. . .
12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	35 000 00	25 000 00	. . .	5
13	{ 450 00 30 006 68 }	. . .	759 35	22 850 00	. . .	. . .	. . .	1 295 308 26	300 000 00	42 657 14	. . .
15	1 641 19	4 906 74	. . .	9 879 70	16 427 63	26 468 67	42 896 30	2 487 371 15	1 775 300 00	641 434 09	abt. 4
16	. . .	. . .	. . .	. . .	. . .	. . .	. . .	154 000 00	125 000 00	17 690 69	4
18	1 949 43	414 27	176 04	. . .	2 539 74	. . .	2 539 74	117 958 82	54 500 00	6 620 42	4

20	$16 677 95	$ 3 736 06	$1 255 35	$ 779 87	$22 449 23	$11 368 74	$ 33 817 97	$3 159 052 82	$1 728 000 00	$181 727 69	4.41
21	20 814 29	1 712 83	. . .	58 934 90	81 461 02	1 277 02	82 738 04	788 440 46	501 000 00	. . .	abt. 3¾
22	9 176 57	8 513 43	6 997 35	34 610 96	59 298 31	. . .	. . .	2 089 285 23	2 100 000 00	915 070 19	4.7
23	. . .	. . .	. . .	. . .	. . .	. . .	. . .	892 336 68	300 000 00	. . .	4¼
24	1 066 31	300 00	700 00	133 62	2 199 93	1 162 26	3 362 19	88 245 63	45 000 00	1 863 81	3½
25	14 749 96	439 16	. . .	7 847 94	23 037 06	. . .	23 037 06	328 378 21	119 320 00	. . .	abt. 3.9
26	. . .	. . .	. . .	. . .	. . .	. . .	. . .	6 470 093 35	6 009 000 00	984 261 28	3.76
27	23 000 00	10 000 00	. . .	. . .	33 000 00	. . .	33 000 00	973 000 00	752 000 00	. . .	4
28	7 169 61	1 159 36	323 02	215 87	8 867 86	{ 155 07[1] / 23 98 }	9 046 91	273 167 89	218 000 00	. . .	4
29	14 219 18	1 589 45	2 524 87	45 849 12	64 182 62	98 272 89	162 455 51	1 937 762 21	400 000 00	6 190 00	4
30	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	527 000 00	131 754 66	abt. 3¾
31	. . .	. . .	. . .	. . .	19 205 59	. . .	19 205 59	785 690 22	175 000 00	. . .	4
32	5 174 62	. . .	. . .	8 694 18	13 868 80	. . .	13 868 80	2 141 263 26	1 475 000 00	541 046 80	5.85
33	7 953 90	3 567 21	2 106 09	39 566 12	53 193 32	8 400 46	61 593 78	1 288 128 54	829 200 00	206 026 54	4
34	. . .	. . .	. . .	. . .	11 678 80	4 013 53	15 692 33	615 986 47	432 000 00	124 718 96	3.88
36	6 921 11	—— 1 14	1 02 ——	. . .	8 062 13	431 83	8 493 96	329 569 59	281 000 00	98 591 96	4
37	. . .	. . .	. . .	. . .	. . .	. . .	. . .	131 614 87	100 000 00	. . .	4
38	4 541 08	985 16	616 14	. . .	6 142 38	. . .	6 142 38	117 675 41	93 000 00	. . .	4
39	. . .	1 046 23	. . .	. . .	1 046 23	12 56	1 058 79	597 697 56	97 650 00	989 55	4
40	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1 640 561 28	1 475 000 00	361 479 68	5.33

[1] To Maintenance Account.

1901. — TABLE 3. — STATISTICS OF CONSUMPTION OF WATER.

Number.	Name of City or Town.	1	2	3	4	5	6	7	8	9	10
		Estimated Population.			Total Consumption for the Year. (Gallons.)	Quantity Used through Meters. (Gallons.)	Percentage of Consumption Metered.	Average Consumption. (Gallons per Day.)			
		Total at Date.	On Line of Pipe.	Supplied at Date.				Total.	To Each Inhabitant.	To Each Consumer.	To Each Tap.
1	Atlantic City, N. J.	32 000 to 250 000	. .	. .	1 245 691 679	. . .	. .	. . .	35 to 75	. .	769
2	Attleboro, Mass.	12 000	11 000	. .	147 946 520	. . .	. .	405 333	34	37	. .
3	Bay City, Mich.	28 000	20 000	16 000	1 082 691 511	214 069 233	20	2 966 278	106	185	1 315
4	Billerica, Mass.	2 800	1 800	1 330	21 946 359	. . .	. .	60 316	. .	45	. .
5	Brockton, Mass.	42 000	38 100	36 600	443 938 118	234 393 952	53	1 216 268	29	33	222
6	Burlington, Vt.	19 000	18 500	18 400	304 685 775	164 581 170	54	835 249	40	44	244
7	Cambridge, Mass.	92 716	92 716	92 716	2 785 156 440	785 936 760	28	7 630 566	81	81	529
8	Chelsea, Mass.	34 000	34 000	34 000	1 095 000 000	134 954 722	12	3 000 000	87	87	488
9	Concord, N. H.	19 632	17 000	. .	. . .	. . .	. .	. . .	. .	. .	. .
10	Fall River, Mass.	107 831	. .	106 631	1 320 839 810	. . .	. .	3 618 739	34	34	. .
11	Fitchburg, Mass.	31 531	. .	27 000	1 022 000 000[1]	. . .	. .	2 800 000[1]	. .	103	. .
12	Freeport, Me.	2 500	800	800	18 045 000	0	0	49 440	62	290	. .
13	Holyoke, Mass.	47 612	47 112	46 612	1 787 750 000[1]	271 491 750	15	4 900 000[1]	103	105	1 321
15	Lynn, Mass.	74 000[2]	. .	72 500[2]	1 644 672 843	390 000 000	24	4 505 953	. .	62	. .
16	Maynard, Mass.	3 500	3 000	2 800	54 884 545	. . .	20	150 368	43	. .	. .

17	Metropolitan W. W. .	844 800	. .	. .	37 044 840 000[3]	. . .	. .	101 492 000	120	. .	. .
18	Middleboro, Mass. . .	{ Town, 7 000 } { F. Dist., 4 300 }	4 100	3 800	81 884 000	41 730 000	51	224 340	52	59	266
19	Minneapolis, Minn. . .	215 000	125 000	115 000	6 591 613 020	1 570 265 250	24	18 059 213	89	. .	. .
20	New Bedford, Mass. .	65 000	58 000	57 000	2 150 199 262	561 404 250	26	5 890 957	91	103	624
21	New London, Conn. .	18 300	17 000	16 000	503 429 000[1]	. . .	. .	1 379 300[1]	75	86	427
22	Newton, Mass. . . .	34 200	33 700	33 400	673 200 749	411 000 000	61	1 843 276	54	55	256
23	Norwich, Conn. . . .	24 637	21 500	20 000	730 000 000[1]	. . .	. .	2 000 000[1]	. .	. .	600[1]
24	Oberlin, Ohio	4 800	3 600	2 800	40 374 000	17 070 000	42	110 600	23	40	168
26	Providence, R. I. . .	193 700	193 700	193 700	3 918 165 542	. . .	60[1]	10 734 700	55	55	484
28	Reading, Mass. . . .	5 000	4 840	4 265	57 479 577	24 260 843	42	157 478	31	37	143
29	Reading, Pa.	81 770	81 500	81 670	2 850 644 804	1 007 909 555	35	7 810 000	96	97	461
30	Schenectady, N. Y. . .	32 000	. .	. .	. . .	. . .	. .	. . .	. .	. .	. .
31	Somerville, Mass. . .	63 500	63 500	63 500	. . .	359 385 082	. .	. . .	. .	. .	. .
32	Springfield, Mass. . .	62 059	54 000	50 000	2 920 000 000[1]	433 077 915	15	8 000 000[1]	129[1]	160[1]	797[1]
33	Taunton, Mass. . . .	31 036	28 000	26 604	631 214 244	227 749 181	36	1 729 354	56	65	374
34	Waltham, Mass. . . .	24 175	23 750	23 700	836 407 890	47 902 226	6	2 291 528	95	97	685
35	Ware, Mass.	8 263	7 783	7 690	116 793 885	65 778 287	56	314 504	38	41	416
36	Wellesley, Mass. . . .	5 240	5 135	5 097	88 975 417	45 467 748	51	245 220	46	47	271
38	Winchendon, Mass. .	5 001	3 000	2 326	31 368 800	11 922 975	39	85 942	17	37	192
39	Woburn, Mass. . . .	14 250	14 200	14 200	426 638 100	46 217 451	9	1 119 556	78	78	383
40	Yonkers, N. Y. . . .	50 000	49 000	48 000	1 495 955 717	. . .	41	4 098 509	82	84	782

[1] Estimated. [2] Lynn and Saugus. [3] Of this, 214 600 000 was furnished from local sources.

1901.—TABLE 4.—STATISTICS RELATING TO DISTRIBUTION SYSTEM.—MAIN PIPES.

Number.	Name of City or Town.	1 Kind of Pipe.	2 Sizes of Pipes. (Inches.)	3 Length Extended During the Year. (Feet.)	4 Length Discontinued During the Year. (Feet.)	5 Total Length in Use. (Miles.)	6 Cost of Repairs per Mile.	7 Number of Leaks per Mile.	8 Length of Pipe Less than 4 Inches Diam. (Miles.)	9 Hydrants. Number Added.	10 Hydrants. Total in Use.	11 Gates. Number Added.	12 Gates. Total in Use.	13 Gates. Number Smaller than 4 Inch.	14 Gates. Number of Blow-off Gates.	15 Range of Pressure on Mains at Center. (Pounds.)
1	Atlantic City, N. J.	C. I.	4 –20	20 093	1 265	51 3	. .	. .	2 2	29	548	. .	. .	. .	9	. . .
2	Attleboro, Mass.	W. I., C. I., C. L.	1 –16	8 229	. .	33 2	. .	0 57	. .	15	278	. .	. .	. .	. .	54– 62
3	Bay City, Mich.	C. I., Wyckoff.	3 –20	8 736	8 003	45 5	$17 18	1 3	0 1	4	417	3	709	1	13	35– 38
4	Billerica, Mass.	C. I.	6 –12	. .	. .	9 7	2 12	1	. .	. .	101	. .	84	. .	4	54–120
5	Brockton, Mass.	W. I., C. L., C. I.	6 –30	17 373	0	68 8	2 29	0 35	. .	42	650	52	848	. .	23	47– 56
6	Burlington, Vt.	C. L., C. I., W. I.,	4 –30	7 399	3 479	39 0	6 86	0 3	2 8	1	214	15	633	59	12	70– 85
7	Cambridge, Mass.	C. I.	1¼–40	4 216	. .	124 3	. .	0 22	3 5	10	978	36	. .	. .	. .	40– 50
8	Chelsea, Mass.	C. I.	6 –16	3 256	. .	38 5	. .	. .	3 6	5	285	10	409	19	31	48– 50
9	Concord, N. H.	. . .	. .	15 345	10 047	61 2	. .	. .	. .	5	272	26	783	. .	. .	. . .
10	Fall River, Mass.	C. I.	6 –24	. .	. .	90 0	. .	. .	. .	37	991	46	986	. .	. .	80
11	Fitchburg, Mass.	C. I.	2 –30	4 789	. .	67 6	. .	. .	. .	13	512	10	564	. .	. .	{ 75 L. S. 155 H. S.
12	Freeport, Me.	C. I., Galv. I.	2 –10	. .	. .	3 8	0	0	1 3	0	19	0	18	4	0	50–100
13	Holyoke, Mass.	W. I., C. I., Ld. L.	½–30	7 625	0	82 9	10 00	0 10	5 7	12	750	36	770	3	31	80–100
15	Lynn, Mass.	W. I., C. L., C. I.	2 –20	2 471	. .	131 8	. .	0 66	. .	7	959	11	977	. .	. .	45– 60
16	Maynard, Mass.	C. I.	4 –12	2 595	0	9 5	0 99	0 5	0	2	90	5	85	. .	2	90– 95
17	{ Met. Water Works	C. I., C. L.	6 –60	11 500[1]	. .	72 0	. .	. .	. .	. .	. .	12	280	. .	. .	. . .
	Met. Water Dist. total in cities and towns }	C. I., C. L., Kal.	4 –60	191 000[1]	. .	1396 5	. .	. .	. .	366	12 279	. .	. .	. .	. .	. . .

18	Middleboro, Mass. .	C. I.	4 -12	392	. .	17 7	. .	0	0	1	121	1	175	0	6	45– 60
19	Minneapolis, Minn.,	C. I., W. I., Steel.	6 -50	38 776	0	276 6	$41 30	0 21	. .	85	3 312	84	2 343	. .	45	. . .
20	New Bedford, Mass.	C. I.	4 -36	13 722	2 302	94 9	20 54	0 3	1 20	12	750	27	1 092	80	97	37– 64
21	New London, Conn.	W. I., C. L., C. I.	4 -24	14 216	0	53 3	9 35	25	3 1	19	277	23	341	. .	30	40– 48
22	Newton, Mass. . .	C. I.	4 -20	7 051	450	137 9	2 00	0 05	2 9	6	961	8	809	47	388	80– 86
23	Norwich, Conn. . .	C. I., W. I.	½-16	436	0	42 8	5 09	0 23	2	3	369	0	418	28	15	81– 94
24	Oberlin, Ohio . . .	C. I.	4 -12	1 820	0	9 7	1 00	0 1	0 3	2	89	3	60	2	2	27– 32
25	Plymouth, Mass. .	C. L., W. I.	2 -20	15 661	2 868	44 4	16 50	2 29	8 6	48	180	106	451	135	32	. . .
26	{ Providence, R. I. .	C. I.	6 -36	35 323	1 114	331 0	0 38	0 06	0	34	1 920	80	3 478	0	32	64– 73 }
	{ H. P. Fire Service	C. I.	12 -24	. .	. .	5 6	. .	. .	. .	0	92	. .	31	. .	4	114 }
27	Quincy, Mass. . .	C. I.	4 -20	21 860	5 035	87 0	. .	1	6	42	576	53	1 044	118	8	80– 85
28	Reading, Mass. . .	C. I.	4 -12	8 134	. .	28 4	0 74	0 035	. .	21	161	9	243	. .	14	68– 78
29	Reading, Pa. . . .	C. I.	1½-36	9 938	4 533	101 7	45 29	0 67	0 9	21	760	82	2 295	15	56	43– 48
30	Schenectady, N. Y. .	. . .	. .	27 274	. .	45 0	. .	. .	. .	75	544	146	865	. .	. .	. . .
31	Somerville, Mass. .	C. I.	4 -20	11 652	. .	86 6	3 15	0 16	. .	29	968	45	1 248	. .	119	60–100
32	Springfield, Mass. .	C. I., W. I., C. L.	1 -36	10 830	2 722	146 2	5 89	0 29	7 7	9	964	35	1 924	371	89	{ 30– 35 L. S. 100–120 H. S.
33	Taunton, Mass. . .	C. I.	4 -20	. .	. .	79 2	26 75	0 23	1 9	11	794	16	563	12	55	45
34	Waltham, Mass. . .	C. I., C. L.	2 -24	8 454	4 224	51 6	3 28	0 2	2 2	13	344	18	695	37	60	50– 70
35	Ware, Mass. . . .	C. I.	4 -12	3 119	0	12 1	. .	. .	0 5	2	116	2	121	10	3	90– 95
36	Wellesley, Mass. .	C. L., C. I.	4 -12	4 362	0	31 1	0 75	0 3	. .	12	282	21	226	3	4	70– 75
37	Whitman, Mass. .	C. I., C. L.	. .	. .	. .	17 5	. .	. .	. .	. .	157	. .	. .	. .	. .	65
38	Winchendon, Mass.	W. I., C. I.	2 -14	7 140	0	16 6	. .	0 42	1	10	131	9	173	28	11	103
39	Woburn, Mass. . .	C. I., C. L.	4 -14	. .	. .	54 0	13 74	1	5	. .	344	. .	423	50	12	70– 75
40	Yonkers, N. Y. . .	C. I.	3 -30	24 165	. .	84 7	21 69	1 7	0 8	62	858	39	550	3	24	. . .

[1] Less length abandoned.

1901.—TABLE 5.—STATISTICS RELATING TO DISTRIBUTION SYSTEM.—SERVICE PIPES.

Number.	Name of City or Town.	16 Service Pipe. Kind.	17 Sizes. (Inches.)	18 Extended. (Feet.)	19 Discontin'd. (Feet.)	20 Total in Use. (Miles.)	21 Service Taps. Number Added.	22 Service Taps. Total in Use.	23 Average Length of Services. (Feet.)	24 Average Cost of Services for the Year.	25 Meters. Number Added.	26 Meters. Now in Use.	27 Percentage of Services Metered.	28 Percentage of Receipts from Metered Water (B) ÷ (C).	29 Motors & Elevat'rs Added.	30 Motors & Elevat'rs Total in Use.
1	Atlantic City, N. J.	C. I., Ld., Gal. I., Tin L.	½– 6	383	. .	0 88	. .	. .	. .	. .	341	3 639	79	. .	.	.
2	Attleboro, Mass.	. . .	. .	. .	. .	. .	. .	. .	. .	. .	325	1 282	. .	. .	.	2
3	Bay City, Mich.	Lead, W. I., C. I.	⅜– 8	. .	. .	. .	55	2 256	. .	. .	55	881	39	60	.	.
4	Billerica, Mass.	Cem. Lined, W. I.	1 – 1½	1 707	. .	2 92	18	225	68 6	. .	20	83	36	51	.	.
5	Brockton, Mass.	W. I., Lead Lined, Cem. Lined, C. I.	¾– 8	12 248	339	34	192	5 467	22 5	$10 85	223	4 523	83	88	2	8
6	Burlington, Vt.	Galv. I., C. I., Lead.	½– 6	2 042	79	18 5	70	3 420	28	8 00	90	2 401	70	81	2	35
7	Cambridge, Mass.	Galv. Iron.	¾– 6	8 246	. .	109	201	14 408	39 8	19 71	1 070	1 898	13	33	7	20
8	Chelsea, Mass.	Lead.	⅝– 2	1 341	. .	31 5	52	6 198	28	12 00	8	113	2	23	.	6
9	Concord, N. H.	. . .	. .	. .	. .	14 57	57	3 278	. .	. .	132	1 142	35	51	.	.
10	Fall River, Mass.	Lead.	½– 2	. .	. .	. .	132	7 075	. .	. .	211	6 755	96	. .	.	.
11	Fitchburg, Mass.	W. I., Cem. L., C. I.	¾– 8	. .	. .	. .	104	4 536	. .	. .	95	2 522	56	. .	3	97
12	Freeport, Me.	Galv. Iron.	½– 2	200	0	1 25	3	170	40	. .	0	0	0	0	0	3
13	Holyoke, Mass.	Cem., Rub. Lined, Enam., C. I., Ld. Lined, Galv. I.	⅝– 4	1 312	. .	13 9	72	3 675	20	15 18	28	238	6	18	1	97
15	Lynn, Mass.	Cem. Lined, Ld. Lined.	¾– 4	. .	. .	97 6	175	12 722	. .	. .	322	2 893	23	. .	.	.
16	Maynard, Mass.	Cem. Lined.	¾	1 212	0	. .	38	536	49	5 56	6	85	20	. .	0	2
17	Met. Water Dist. total in cities and towns	. . .	. .	. .	. .	. .	4 044	138 540	. .	. .	645	11 030	8	. .	.	.
18	Middleboro, Mass.	W. I., Cem. Lined, Ld.	¾– 3	1 058	112	9 35	25	844	58	. .	20	369	43	66	0	7

19	Minneapolis, Minn.	Lead, Galv. Iron.	⅝– 1	. .	. .	. .	. .	20 577	. .	. .	1 117	6 333	31	. .	0	20
20	New Bedford, Mass.	Lead, C. I.	½–10	4 139	2 457	61 41	167	9 447	34 3	. .	137	1 566	17	32	9	125
21	New London, Conn.	{ W. I., Cem. Lined, Galv. I., C. I., Lead. }	½– 4	2 392	139	11 7	141	3 229	19 2	$10 78	22	251	8	. .	0	17
22	Newton, Mass. . .	Galv. I., Tarred I., Ld.	¾– 6	10 075	3 021	80 3	100	7 181	59	27 73	209	6 109	85	96	0	17
23	Norwich, Conn. . .	W. I., Lead.	½– 6	997	75	15 5	42	3 500[1]	23	. .	0	112	3	20	2	42
24	Oberlin, Ohio . . .	Galv. Iron, Lead.	¾– 2	. .	. .	. .	35	660	25	8 00	41	432	75	85	0	0
25	Plymouth, Mass. .	Lead, Cem. Lined.	½– 4	825	. .	6 1	82	1 975	16 3	5 61	. .	. .	. .	. .	0	1
26	Providence, R. I. .	Lead, C. I.	½–10	. .	. .	. .	701	22 186	. .	. .	731	18 544	84	. .	4	165
27	Quincy, Mass. . .	Lead Lined.	¾	26 000	. .	. .	300	4 630	40	15 00	22	147	3	. .	.	.
28	Reading, Mass. . .	{ C. I., Galv. I., Cem. Lined, Ld. Lined. }	¾– 6	2 774	150	14 6	48	1 104	69 9	24 15	25	987	89	. .	.	3
29	Reading, Pa. . . .	Ld., W. I., C. I., Ld. L'd.	½– 8	. .	. .	. .	577	16 942[1]	. .	. .	95	814	5	24	1	8
30	Schenectady, N. Y.	. . .	. .	. .	. .	. .	646	7 716	. .	. .	600	. .	. .	. .	.	.
31	Somerville, Mass. .	{ Ld., Ld. Lined, Cem. Lined. }	½– 6	8 733	. .	66 8	229	10 520	. .	18 26	22	224	2	24	0	8
32	Springfield, Mass. .	{ Ld., Cem. Lined, Tarred, Galv. I., C. I. }	½– 6	. .	. .	. .	270	10 034	. .	. .	215	3 337	33	32	24	245
33	Taunton, Mass. . .	Cem. Lined, Tin Lined.	¾– 3	. .	. .	44 5	131	4 618	. .	. .	102	1 934	42	. .	1	17
34	Waltham, Mass. . .	C. I., W. I.	¾–12	7 330	952	39 8	70	3 345	76	43 35	12	93	3	12	0	6
35	Ware, Mass. . . .	Cem. Lined.	1 – 2	4 840	845	9 5	21	755	62 2	. .	21	754	100	. .	0	10
36	Wellesley, Mass. .	{ C. I., Cem. Lined. Ld. Lined. }	½– 6	3 132	326	66 1	32	898	98	15 77	24	854	100	. .	0	0
37	Whitman, Mass. .	. . .	. .	. .	. .	. .	. .	1 008	. .	. .	. .	477	44	. .	.	.
38	Winchendon, Mass.	W. I.	1 – 2	2 840	0	4 1	62	447	47	15 89	58	434	97	99 7	0	0
39	Woburn, Mass. . .	Ld. Lined, Cem. Lined.	1	. .	. .	. .	31	2 925	. .	21 56	7	74	2	14	.	9
40	Yonkers, N. Y. . .	Lead, C. I.	⅜– 8	. .	. .	. .	270	5 238	. .	. .	304	5 156	99	. .	1	10

[1] Estimated.

PROCEEDINGS.

June Meeting.

Boston, June 25, 1902.

The June meeting of the Association was devoted to a boat excursion down Boston Harbor, a shore dinner at Nantasket Point, Hull, and a visit to the works of the Fore River Ship and Engine Company, at Quincy.

The attendance was as follows: —

Members.

C. F. Allen, E. W. Bailey, Charles H. Baldwin, L. M. Bancroft, C. H. Bartlett, J. E. Beals, J. W. Blackmer, George Bowers, G. A. P. Bucknam, Edward W. Bush, L. Z. Carpenter, E. J. Chadbourne, J. C. Chase, F. W. Clark, M. F. Collins, B. I. Cook, H. A. Cook, J. W. Crawford, A. O. Doane, L. S. Doten, E. R. Dyer, August Fels, R. J. Flinn, Fred B. Forbes, F. F. Forbes, E. V. French, A. D. Fuller, H. F. Gibbs, J. C. Gilbert, T. C. Gleason, Albert S. Glover, F. W. Gow, E. H. Gowing, J. O. Hall, V. C. Hastings, H. G. Holden, J. A. Huntington, Willard Kent, C. F. Knowlton, N. E. Mather, W. E. Maybury, N. A. McMillen, F. E. Merrill, H. A. Nash, Jr., Thomas Naylor, F. L. Northrop, C. E. Peirce, J. H. Perkins, C. E. Riley, W. W. Robertson, H. E. Royce, P. P. Sharples, E. M. Shedd, C. W. Sherman, Wm. B. Sherman, G. H. Snell, J. A. St. Louis, G. A. Stacy, J. T. Stevens, W. F. Sullivan, F. L. Taylor, L. A. Taylor, R. J. Thomas, H. L. Thomas, Wm. H. Thomas, D. N. Tower, W. W. Wade, C. K. Walker, J. C. Whitney, F. B. Wilkins, G. E. Winslow, E. T. Wiswall. — 72.

Associates.

Ashton Valve Co., by C. W. Houghton; Harold L. Bond & Co., by G. S. Hedge; Chapman Valve Mfg. Co., by Edward F. Hughes; Chas. A. Claflin & Co., by Charles A. Claflin; Garlock Packing Co., by Horace A. Hart; Hersey Mfg. Co., by Albert S. Glover; Lead Lined Iron Pipe Co., by T. E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by J. G. Lufkin and Charles H. Baldwin; Neptune Meter Co., by H. H. Kinsey; Norwood Engineering Co., by H. W. Hosford; Perrin, Seamans & Co., by James C. Campbell; Rensselaer Mfg. Co., by F. S. Bates; A. P. Smith Mfg. Co., by W. H. Van Winkle; Sweet & Doyle, by H. L. DeWolfe; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by J. K. P. Otis, Edward P. King, F. L. Northrop, and C. L. Brown. — 21.

GUESTS.

H. F. Peck, H. L. Thayer, and Mrs. E. J. Chadbourne, Wakefield, Mass.; Elmer P. Vaughan, Oakland, Cal.; Mrs. Edward M. Shedd, Somerville, Mass.; Mrs. Wm. B. Sherman, Providence, R. I.; J. J. Moore, Hingham, Mass.; Capt. and Mrs. Albion Miller, New Orleans, La.; George Hardwick, E. J. Johnson (City Engineer), and Mrs. H. G. Holden, Nashua, N. H.; Mrs. C. S. Proctor, Mrs. A. Fels, Misses Fels, Ellen M. Weaver, F. L. Weaver, Mrs. Bucknam, Miss Hillman, Mr. and Mrs. Kelly, Mrs. J. W. Crawford, Mrs. George Bowers, Miss Bowers, and W. J. Dowd, Lowell, Mass.; Miss Emma L. Hastings, Concord, N. H.; J. F. Gleason, Quincy, Mass.; John W. Churchill (Water Commissioner), Plymouth, Mass.; Mrs. Charles W. Sherman, Belmont, Mass.; John H. Cook, Paterson, N. J.; Charles H. Choate (President Board of Aldermen), Joseph James (Master Mechanic Pacific Mills), A. H. Robinson, Daniel Gallagher, Charles H. Donovan, J. J. Desmond, and E. L. Arundel (Members Water Board), Lowell, Mass.; Walter L. Beals, Chester E. Weston, and Amos H. Eaton (Chairman), Middleboro, Mass.; J. G. Manuel (Assistant Superintendent) and L. P. Stone, Natick, Mass.; T. J. Flinn, H. M. Flinn, and T. T. Hubbard, West Roxbury, Mass.; Charles F. Merrill, Fred E. Warren, Miss Soule, and Charles E. Parks, Somerville, Mass.; Joel C. Gleason, S. W. Gleason, Mrs. J. A. St. Louis, Mrs. George A. Stacy, Mr. and Mrs. C. B. Russell, and A. F. Berry, Marlboro, Mass.; Mr. and Mrs. G. T. Staples, Dedham, Mass.; Mrs. Thomas Naylor and H. Naylor, Maynard, Mass.; Mr. Cannon (Water Registrar), Clinton, Mass.; Mrs. F. W. Clark, Newton Highlands, Mass.; Mrs. W. E. Maybury and Mrs. James T. Stevens, Braintree, Mass.; W. H. Hawkins and Miss Hawkins, Binghamton, N. Y.; Mrs. C. F. Knowlton and Mrs. J. F. Gleason, Quincy, Mass.; B. Sturgard, Lynn, Mass.; George H. Lamson and Mrs. Mary E. Lee, Woodward, Ia.; Mrs. C. E. Peirce, East Providence, R. I.; A. R. McCallun (Superintendent) and C. F. Allen, Whitman, Mass.; Mrs. C. W. Houghton, Mrs. C. C. Dalton, Mr. and Mrs. B. L. Arey, H. M. Crossland, J. A. Mitsch, Capt. E. W. Sears, and W. H. Greenwood, Boston, Mass. — 83.

SUMMARY OF ATTENDANCE.

Members	72
Associates	21
Guests	83
	176
Counted twice	2
Total attendance	174

A short business meeting was held on the boat, with President Merrill in the chair, and the following candidates for membership, who were recommended by the Executive Committee, were elected :—

Resident Members.

George K. Boutelle, Treasurer Kennebec Water District, Waterville, Me.

John H. Flynn, Assistant Superintendent Boston Water Works, Roxbury, Mass.

Edward J. Johnson, City Engineer, Nashua, N. H.

Clarence A. Perkins, Water Commissioner, Malden, Mass.

George T. Staples, Superintendent Water Works, Dedham, Mass.

Norman W. Stearns, Civil Engineer, Roxbury, Mass.

Thomas H. Wiggin, Civil Engineer, Boston, Mass.

Frederick W. Witherell, Assistant in Engineering Department, State Board of Health, Winchester, Mass.

Non-Resident Members.

Kenneth Allen, Engineer and Superintendent of Water Works, Atlantic City, N. J.

H. N. Blunt, Assistant Superintendent Palmer Water Company, Palmerton, Pa.

Theodore Horton, Civil Engineer, New York City.

Charles Gilman Hyde, Assistant Engineer in charge of filtration, Harrisburg, Pa.

Announcement was made that the headquarters of the Association during the Annual Convention, which will be held in Boston, September 10, 11, and 12, will be at the Hotel Brunswick, Boylston Street.

Adjourned.

Meeting of the Executive Committee.

Boston, June 25, 1902.

The Executive Committee met on board the boat, before the meeting of the Association, with President Merrill in the chair, and present also Messrs. C. K. Walker, H. G. Holden, G. A. Stacy, L. M. Bancroft, C. W. Sherman, W. B. Sherman, R. J. Thomas, and Willard Kent, Secretary.

Twelve applications for membership were received, and it was voted to recommend the applicants to the Association for election.

The sub-committee on Annual Convention reported that it had selected as headquarters, during the convention, the Hotel Brunswick, Boylston Street, Boston.

Adjourned.

OBITUARY.

William Downey, elected a member of this Association June 14, 1899, died October 1, 1901.

Mr. Downey entered the water department of Worcester, Mass., in 1883. He was employed in various capacities until about 1895, when he was made general foreman in charge of outside work, which position he held at the time of his death. He was forty-three years old, and left a wife and two children.

Joseph C. Hancock, superintendent of Water Works at Springfield, Mass., died on July 12, 1902, at the age of seventy.

Mr. Hancock was one of the original members of the Association, his membership dating from June 21, 1882. He had been superintendent of the Springfield Water Works for thirty-eight years.

Frank E. Fuller, who was elected a member of this Association on March 14, 1900, died on August 1, 1902.

Mr. Fuller was born April 28, 1871; he was graduated from the Newton High School in 1890, and entered the Chandler Scientific School of Dartmouth College, but was forced to leave before the completion of the first year by a serious illness, which permanently undermined his health. In 1892 he entered the office of the city engineer of Newton; in 1895 he was employed in the engineering department of the Boston & Albany R. R. In 1897 he entered the employ of the engineering department of the Metropolitan Water Works, where he remained until December of 1901, leaving to take a sea voyage for his health. He finally reached Santa Cruz on the island of Tenerife, where he died after a lingering illness. He left a wife, but no children.

BOOK NOTICES.

"Diagrams of Mean Velocity of Uniform Motion of Water in Open Channels; Based on the Formula of Ganguillet and Kutter." By Irving P. Church, C.E., Professor of Applied Mechanics and Hydraulics, College of Civil Engineering. Cornell University. John Wiley & Sons, New York. Price $1.50.

Professor Church says: "It is perhaps quite generally admitted among hydraulic engineers that on account of the uncertainty usually attending the choice of a proper 'coefficient of roughness' (n) in the use of Kutter's formula. it is well-nigh useless to observe great refinement in the employment of that well-known equation for the mean velocity of uniform motion of water in open channels. Suitable diagrams, therefore, can furnish solutions of this equation which answer every practical purpose. A collection of such diagrams is here presented, one for each of eleven values of 'n.' (from .009 to .035), and ranging from 0.1 feet to 25 feet in the value of R, the hydraulic radius, the slope varying from 0.01 feet per thousand to 100 feet per thousand (that is, from $S = 0.00001$ to $S = 0.100$)."

The diagrams are very clear, and should be of much value to hydraulic engineers.

NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. XVI. December, 1902. No. 4.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE WATER SUPPLY OF NASHUA, N. H.

BY HORACE G. HOLDEN, SUPERINTENDENT, NASHUA, N. H.

[*Read September 10, 1902.*]

Has it ever occurred to you what great changes have been made during the past twenty years in the water systems of this country? Formerly nearly all of the works derived their supplies from surface waters, either lakes, ponds, or running streams. These supplies were supposed to be unlimited in quantity and were apparently all right in quality; but the large increase of population, the building up of manufacturing industries, together with summer resorts on the shores of the lakes and streams, have caused many of the water supplies to be so contaminated with sewage, consisting of house drainage and mill refuse, as to not only render them unfit for domestic use, but also for steam boilers and other purposes where pure water is required.

To remedy this condition, filter systems were introduced on many of the works. Some of these have proved successful, while others have been failures; but it is doubtful if the average water taker can ever be convinced that liquid sewage can be so strained or clarified that it will not still remain liquid sewage.

For a period of forty-seven years, from 1853 to 1900, the city of Nashua, N. H., received its entire water supply from Pennichuck Brook, the outlet of a chain of ponds located in the town of Hollis. After leaving what is called the Big Pennichuck Pond the brook flows for six and one-half miles, as shown on the map, Fig. 1, forming the boundary line between the city of Nashua and the town of Merrimack, until it finally reaches the Merrimac River, about three miles above the Hudson Bridge.

In 1853 the water company built the first stone dam, about three-

fourths of a mile above the mouth of the brook. (Plate I, Figs. 1 and 2.) This dam is twenty-six feet in height, and the reservoir formed by it flows back eighteen hundred feet, to where another stone dam,

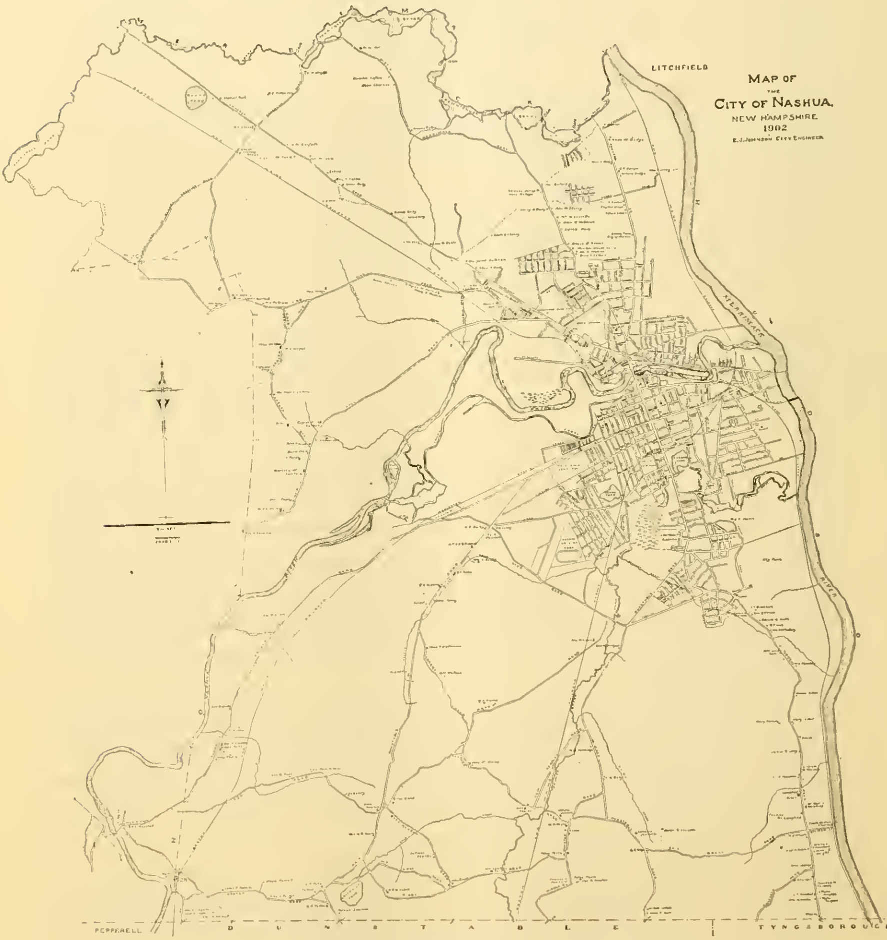


FIG. 1.*

thirty feet high, is located. Beyond this dam there are two more dams, each forming a reservoir of over a mile in length.

At the first or lower dam there are three pumping stations. The

*The upper part of the map shows the location of the Pennichuck Brook and reservoirs.

Fig. 1. — First or Lower Dam on Pennichuck Brook. Pumping Stations Nos. 1 and 3.

Fig. 2. — Lower Reservoir and Pumping Stations.

No. 1 Station was built in 1853. It has a three-million-gallon steam pump and a two-million-gallon power pump. No. 2 Station was built in 1893, and has an eight-million-gallon triple expansion steam pump. No. 3 Station is located below the dam. It was built in 1900, and has a six-million-gallon power pump, the wheel driving it being run by water flowing through a seventy-two-inch steel penstock leading from the reservoir formed by the second dam, giving a head of sixty feet of water on the wheel. The second dam is shown in Plate II, Fig. 1.

The penstock is intended to be of sufficient size to carry all the water that ever runs in the brook, so that at present no brook water gets into the lower reservoir, from which is pumped the water now used by the city of Nashua.

The land on both sides of the brook from its mouth up to the fourth dam, a distance of three and eight-tenths miles, is now principally owned by the water company, which controls an area of nearly one thousand acres. This land was formerly used for grazing and tillage, but since coming into the possession of the water company it has been allowed to grow up into woodland, so that at present most of it is covered by quite a heavy growth of white pine, and this practically eliminates all danger of any outside contamination to the brook.

In 1892 Mr. Frederic P. Stearns, who at that time was the chief engineer of the Massachusetts State Board of Health, made a careful examination of the brook, and in his report to me mentions that the amount of albuminoid ammonia (organic matter) is unusually low. He also says: "I have compared it with a list of one hundred and four surface waters in Massachusetts and find there are but twenty-five lower, and seventy-nine higher. Of the twenty-five lower, all but two or three are mountain streams or small reservoirs fed by springs."

We have had here what might be considered an ideal water supply, with storage reservoirs of sufficient capacity to furnish a daily supply of at least ten million gallons of practically pure water, even in the dryest seasons, provided that the pumping was done by steam power. And even of late years the only question that has ever been brought up regarding the quality of the water was that, as is the case with most surface waters, there were times, especially in the spring of the year, when the water was discolored and also developed a decidedly swampy taste, undoubtedly caused by the meadows which line the upper end of the brook.

However, without much searching or any expectation of ever getting a better water supply, we accidentally came across one which is in every way superior to our brook supply.

About one eighth of a mile south of our lower reservoir there is a meadow containing about five acres, which has always been noted for having a number of springs of remarkably pure water. At times when our city water developed the swampy taste, many of the citizens of Nashua would occasionally drive up to these springs to fill their jugs and bottles with this spring water. The water company had owned this meadow for several years, and in order to accommodate those who preferred spring water, I laid a plank walk into the meadow to what was considered the best spring, and one day took up a twenty-four inch cement pipe, three feet long, such as is used in sewer work, intending to settle this pipe into the ground, so as to be nearly level with the surface of the water, then clean out the mud from the inside of the pipe, leaving a good well, from which the water could be dipped without affecting its clearness.

On ending the pipe up over the spring, I was surprised to find that by the time the pipe had settled a foot into the meadow, the water came up inside the pipe so as to flow over the top, which was about twenty-four inches above the level of the surrounding ground.

The level of the meadow is twenty-four inches above the high-water line of the lower reservoir, and there was what had once been a water-course leading from the meadow to the reservoir, but which had been filled up with decaying vegetation, — dead trees, etc. After clearing out this channel, there was quite a flow of water from the meadow into the reservoir.

Just before reaching the reservoir, the water-course runs through a narrow gorge about ten feet wide, with nearly vertical sides some twenty feet high. At this point a small dam twenty-four inches in height has been built, with a weir for measuring the flow of water from the meadow. The flow over this weir was very uniform, never at any time being less than one million gallons per day, while the maximum daily flow was rarely over 1 250 000 gallons.

The next season I drove several two and one-half inch pipes in different sections of the meadow, and succeeded in getting a good stream of water to flow from each of them. I then sunk a six-inch wrought-iron pipe in the north section of the meadow to the depth of 32.75 feet. There is a continuous flow from this pipe of 274 gallons per minute, or nearly 395 000 gallons per day.

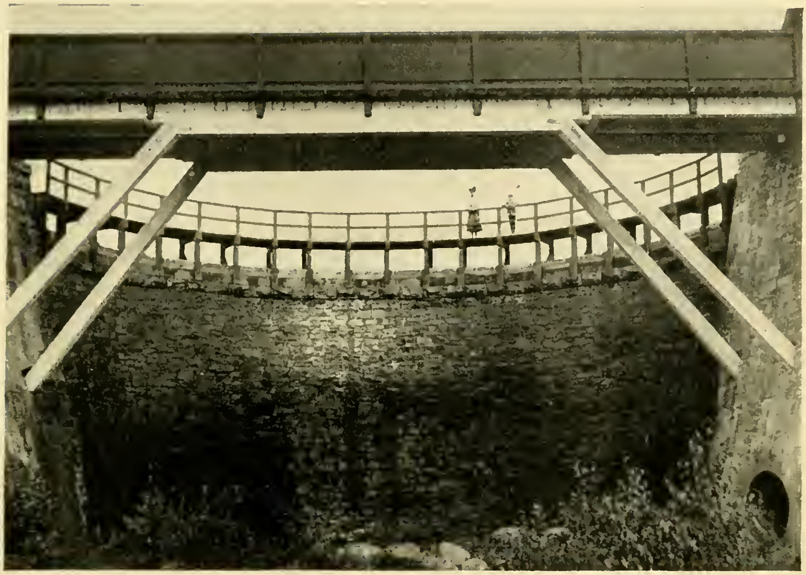


FIG. 1.—SECOND DAM ON PENNICHUCK BROOK.

FIG. 2.—THE PENNICHUCK SPRINGS. SHOWING THE 6-INCH AND TWO 2½-INCH FLOWING WELLS.

The surface of the meadow is covered with a layer of muck or loam, varying from one to six feet in depth. Below this, as was indicated by samples taken while driving the six-inch pipe, there appear to be alternate layers of marl, sand, fine gravel and coarse gravel, the water flowing mostly from the gravel layers. In driving the two and one-half inch pipes, a very good flow of water would occasionally be obtained from a depth of fifteen or sixteen feet, then, on driving farther, the flow would stop entirely, but on driving still deeper the flow would commence again.

Accurate measurements of the flow would be taken at every foot at which the pipe was driven, and after driving as far as could be easily done, the pipe would be drawn up to the place where the greatest flow was obtained. After driving the six-inch pipe previously mentioned, twelve 2½-inch pipes were driven, commencing at a point thirty-eight feet south of the six-inch pipe and running west in a straight line one hundred and sixty-eight feet, making the average distance between the pipes fourteen feet. Some of these wells are shown in Plate II, Fig 2. The depth at which the greatest supply of water was obtained from these pipes varied from sixteen feet seven inches to thirty-one feet eight inches. The flow from each pipe varied from 19.4 to 41.4 gallons per minute, the total flow from these twelve pipes being 352.9 gallons per minute, or 408 166 gallons per day.

Another line of six 2½-inch pipes was driven at the extreme southerly end of the meadow, the average distance between the pipes being seventeen and one-half feet. The greatest flow from these pipes was obtained at from thirty-six to fifty-two feet in depth, this flow being from 23.1 to 46.1 gallons per minute. The total flow from these six pipes is 273 744 gallons per day.

There is a daily flow from the six-inch pipe, and the eighteen 2½-inch pipes, amounting to 1 127 520 gallons. During the past three years I have frequently measured this flow and found but slight variation.

These wells increase the flow of water over the weir to about two and one-half million gallons per day, and whenever the pipes are plugged, the flow on the weir decreases proportionally, showing that the surface springs are not affected by the wells.

From these tests, I feel confident that a large number of pipes might be driven in this meadow and a very large amount of water obtained.

The following is a report of an analysis of water taken from one of the surface springs by Henry J. Williams, of Boston, chemical engineer and analytical chemist.

	Parts per 100 000.
Total Solids	3.7
Volatile and Organic Matter	0.5
Fixed Solids or Mineral Matter	3.2

The mineral matter contains : —

Silica	trace
Sesquioxide of Iron	faint trace
Alumina	none
Lime	1.42
Magnesia	0.14
Sulphuric Acid	0.498
Chlorine	0.20
Degree of Hardness	1.5
Free Ammonia	0.001
Albuminoid Ammonia	0.003

The above results show very plainly that this "spring" water is a very soft and unusually pure water, both in its freedom from organic matter and its freedom from mineral matter. Its purity in these two respects is unusual, and it is, therefore, admirably fitted for household use and for drinking. The amount of chlorine which the water contains is also very low, while the trifling amounts of mineral matter which are present are of entirely unobjectionable nature.

The constituents found in the analysis of the mineral matter occur in the water in the following probable states of combination : —

	Parts per 100 000.
Silica	trace
Sesquioxide of Iron	faint trace
Alumina	none
Sulphate of Lime	0.847
Carbonate of Lime	1.912
Chloride of Magnesia	0.210
Carbonate of Magnesia	0.126
Sodium Chloride	0.071
	3.166

The water also has a neutral reaction, that is, it is neither acid nor alkaline.

During the summer months the temperature of the water as it flows from the pipes is about forty-six degrees, but about the first of October the temperature gradually increases, and reaches sixty-three degrees by December, and by the last of April drops back to forty-six degrees. Professor Sedgwick informs me that this change of temperature is probably caused by the water flowing underground from a long distance, and if his theory is correct (as I have no reason to doubt) it may be possible that this water comes from a continuation of the underground river which Professor Denton, formerly of Harvard College, is said to have traced from Narragansett Bay to the New Hampshire state line, according to an item which was published in February, 1902, in several Massachusetts papers. This item related to the suit of Hollingsworth and Vose against the town of Foxboro, for taking water for water supply purposes from the Neponset River. The town claimed, however, that their supply, which is taken from wells, is derived from a subterranean river.

About one and one-half miles southwest of our springs there is another meadow similar to the one I have described, in which I drove a few pipes and was successful in getting flowing wells. This property is now owned by the United States Fish Commission, who get from flowing wells enough water to supply all the requirements of their fish hatcheries.

A NEW TURBIDIMETER.

BY CHARLES ANTHONY, JR., CIVIL ENGINEER, GLENVIEW, HEREFORD, ENGLAND.

[*Read September 11, 1902.*]

The determination of the turbidity of water is a factor which now occupies a more prominent position in deciding on the organoleptic qualities of a public water supply than formerly. Nevertheless, there are few points on which greater diversity of procedure exist; and among the many methods employed none can be considered altogether satisfactory.

These methods can all be resolved into one or other of the following three classes: —

1. The gravimetric.
2. The photometric.
3. The use of standards of comparison.

The first may be called the standard method, at all events from the water analyst's point of view. Indeed, formulæ have usually been applied to determinations by other methods, with the object of reducing them to equivalent weights of suspended matter in parts per million. But seeing that the finely suspended matter, consisting generally of clay and silica, is entirely harmless, and that it is only the appearance they impart to the water which is considered by the consumer, this proceeding appears unnecessary, not to say tautological.

The following are the principal methods hitherto employed in estimating turbidity: —

1. The gravimetric.
2. Lovibond's tintometer (colored glass standards, depth of tints varied).
3. Tidy's colorimeter (colored solution standards, thickness of solution varied).
4. Boston commissioners' colorimeter (colored glass standards, thickness of water varied).
5. Platinum and cobalt chloride standard (concentration of solution varied).

6. Silver chloride standard (concentration of solution varied).
7. Leed's Nessler standard (concentration of solution varied).
8. Stokes' Nessler standard (thickness of solution varied).
9. Kaolin standard (amount of kaolin varied).
10. Silica standard (amount of silica varied).
11. Horning's diaphanometer.
12. Hazen's platinum wire standard.
13. Salback's photometric method.

The first, or gravimetric, may be dismissed as being a difficult and tedious method, giving only approximate results, even in the hands of a capable water analyst, working in a well-equipped chemical laboratory.

The second, Lovibond's tintometer, is not well adapted to the examination of water, and is, as its name implies, not a measure of turbidity but rather of color. Its scale is, moreover, entirely arbitrary.

The third, Tidy's colorimeter, requires the preparation of standard solutions, has a restricted scale, and labors under the same disadvantages as the last.

The fourth, Boston commissioners' colorimeter, is open to the same objections as those above described.

The fifth, platinum and cobalt standard, though well recognized as a standard of color, is not a measure of turbidity, and is open to the same objection of arbitary scale as the above.

The sixth, seventh, and eighth are arbitrary standards which represent no rational scale, either as to the amount of suspended matter by weight, or amount of light absorbed.

The ninth and tenth are means of obtaining, by comparison with known standards, an approximate idea of the weight of matter in suspension, more easily than by the gravimetric method.

The eleventh, twelfth, and thirteenth are methods depending upon photometry. The eleventh, Horning's diaphanometer, depends upon the limiting depth at which an object remains visible through a tube of water; the twelfth, Hazen's platinum wire, upon the depth at which a platinum wire of one millimeter diameter becomes invisible in the water under examination; and the thirteenth, Salback's, is simply a photometer of cumbersome construction, necessitating the use of two artificial lights of equal intensity.

Of all these, as a turbidimeter in contradistinction to a colorimeter, the twelfth, Allen Hazen's platinum wire method, is the most practical. It is, indeed, the acme of simplicity, but labors under

two serious drawbacks: that its scale — the reciprocal of the depth in inches at which the wire becomes invisible — is entirely arbitrary, and that observations made under different conditions of illumination are not strictly comparable. It may be dismissed, therefore, as not a strictly accurate or scientific method, though useful in practice in certain cases on the score of simplicity.

From the above it may be seen that all hitherto employed methods are deficient, either on the score of difficulty and tediousness, or on account of irrational scale and deficient accuracy. In consequence some simple photometric method of measuring the absolute amount of light absorbed by a given thickness of water appears to the writer the most rational and convenient method of estimating the degree of turbidity of a water, and with this object he has designed the form of instrument illustrated in the following figure (Fig. 1).

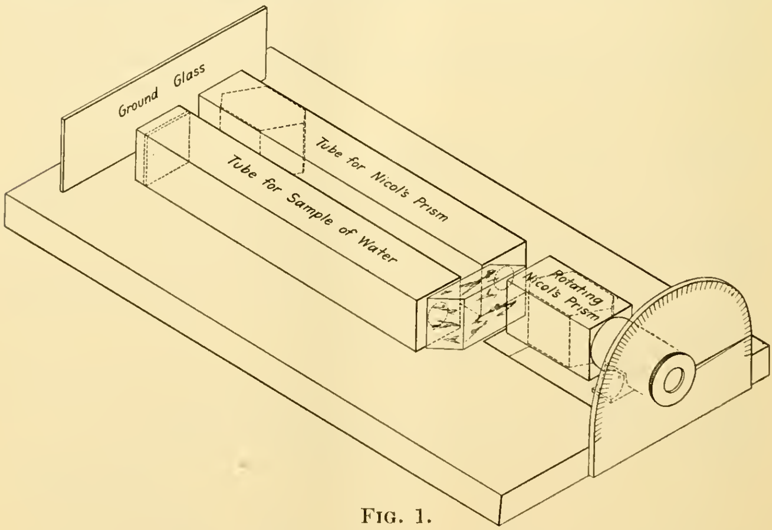


FIG. 1.

It consists, as will be seen, of a couple of parallel tubes of standard length, say fifty centimeters, one of which, closed at the ends by plates of glass, contains the water to be examined. Light transmitted preferably through ground glass reaches the eye, in part through this water and in part direct after passing through a Nicol's polarizing prism. These two sources of light are observed through an eyepiece containing another Nicol prism. The field of view is thus seen neatly dichotomized. By rotating the eyepiece, the illumi-

nation of that half of the field which received its light direct, seeing that it has already passed through a Nicol prism, can be varied until it matches the half receiving light through the standard thickness of water under examination. And though the inevitable difference in tint introduces some error due to personal equation in estimating equal obscuration, the extremely convenient manner in which the lights from the two sources are seen in absolute juxtaposition in the same field of view, allows of more accurate comparison than by any of the methods hitherto suggested. Further, seeing that the obscuration varies, according to a well-understood relation, with the angle through which the eyepiece is rotated, the instrument can be made to indicate, on a properly graduated disc, the degree of obscuration, that is, turbidity, to a rational scale, in which 1 represents perfect transparency and 0 total obscuration.

In conclusion it may be pointed out that the instrument is most easy to handle, gives accurate results to a rational scale, and is independent of the source of light. For these reasons the writer believes it well adapted to fill the long-felt want of a ready and standard means of making turbidity observations.

DISCUSSION.

The President. I will call upon Mr. Hazen to say something upon the subject of Mr. Anthony's paper.

Mr. Allen Hazen.* Mr. President, this method of determining turbidity is an absolutely new one to me. It looks like a very interesting method; and I should very much like to see an apparatus constructed according to this illustration, and compared experimentally with some of the methods of measuring turbidity with which we have had practical experience.

The author seems to be not quite clear in his distinction between color and turbidity. The two things are so different that no one who has had experience with them both would think of measuring them on the same scale, and the author is evidently not quite clear as to the distinction when he lists the methods of measuring color with the methods of measuring turbidity.

The objections to the wire method, which the author mentions in so complimentary a manner, have been fully recognized by us for a long time. The method was based on methods which have been used from a very early time, and was put in use at Lawrence thirteen

* Civil Engineer, New York, N. Y.

years ago. Some work was being done for which a definite scale for recording the turbidities of certain waters was absolutely necessary. The scale was arbitrary. It had to be arbitrary. There were no data available at the time to make a scale in any other way. Since that time a great many data have been collected bearing on what a rational scale should be, and, as I hope to tell you this afternoon,* a scale has been constructed based upon these data which approximately meets the actual conditions, so that the figures as read are directly proportional to the amount of turbidity-producing material in the water. And this is, I believe, the object to be sought in making a turbidity scale.

The other objection mentioned to the wire method, that the results vary according to the light, is less serious in practice than might be at first supposed. Certain regulations are made in regard to the amount of light, which are followed as far as possible, and within the limits specified the differences do not cause a considerable error in the results.

There is a third source of error which seems to have escaped the attention of the author, but which is quite as important as those mentioned, and that is the differences in the eyes of different observers. This also is a matter which has to be guarded against, and is best done by comparing the readings of different people on the same water, and making sure that the observers whose records are relied upon have normal eyes and secure results approximately the same as those of other people with good eyesight.

The method of measuring turbidity proposed by the author is certainly a most interesting one, and I hope it will be investigated and compared with some of the other methods about which we know so much.

Mr. F. N. Connet.† Perhaps there are some others in the room who, like myself, once knew what a Nicol's prism is, but have forgotten. My recollection is that it is a polarizing instrument, but I am not quite sure of that. If there is anybody in the room who can explain it, I think it would be interesting to have it explained.

Mr. C. W. Sherman.‡ Mr. President, I will not attempt to give a scientific explanation of it, for my recollection is nearly as dim as

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* See paper, "The Physical Properties of Water," to appear in the next issue of the Journal. — Ed.

† Mechanical Engineer, Builders Iron Foundry.

‡ Assistant Engineer, Metropolitan Water Works, Boston, Mass.

Mr. Connet's. I do not remember what the material of the Nicol's prism is, but I know it polarizes light, and with two Nicol's prisms, setting the planes of polarization at right angles one to the other, the polarized light can be entirely obscured. By a rotation, such that the plane of one prism will be at right angles with the plane of the other, the obscuration of light passing through the tube containing the first Nicol's prism would be complete, while with the planes parallel the light would be transmitted without obscuration.

That suggests a possible lack of sensitiveness in the use of this instrument, since there is only a ninety-degree angle of rotation from total illumination to total obscuration; reading on the silica standard of water, as we do on our Metropolitan supply, — where we read gradations of turbidity varying from two or three points at ordinary times to more than a hundred when the streams are in freshet, — and with the muddy waters of the West, they may go, for all I know, to a thousand; it would be decidedly difficult to read all the gradations that one might want in ninety degrees of rotation.

It seems to me that Mr. Anthony in devising this instrument has apparently gotten hold of a similar idea — not in making use of polarized light, but in the construction of the instrument — to that of the FitzGerald and Foss colorimeter which has been used for something over ten years on the Boston and Metropolitan Water Works, and which was described to this Association by Dr. Frederick S. Hollis three or four years ago.* That instrument consists of two parallel tubes, in one of which the water to be examined is placed to a standard depth, and into the other of which platinum and cobalt standard is forced by means of a bulb to a varying depth, until the colors are matched in an eyepiece constructed to show light from both tubes at once in the same way that Mr. Anthony's would do. It is, however, not a turbidimeter. I should judge that Mr. Anthony had not known of this colorimeter, because he does not mention it, although he lists color determinations as well as turbidity determinations proper in the methods which he states have been used with the intention of estimating turbidity.

I think perhaps Mr. Anthony was fully cognizant, or, at least, more fully cognizant of the difference between turbidity and color than Mr. Hazen infers, since he states, after listing these methods, that several of them are simply measures of color; but I think it is undoubtedly a fact, and probably that is what Mr. Anthony intended to convey, that

* JOURNAL, Vol. XIII, p. 94.

some of these methods have been used with the intention of estimating turbidity, although they are properly merely measures of color.

Mr. Anthony (by letter). In answer to Mr. Hazen's remarks I would observe that his new method of graduating the platinum wire turbidimeter had not been made public by the United States Geological Survey at the time my communication was prepared. Though this method is a distinct improvement on the original arbitrary one, I may point out that it is put forward as a tentative one, subject to alteration, and that it does not overcome errors due to differences in observers or in observing conditions.

The instrument I suggest would, of course, as Mr. Sherman points out, have a range embraced within a rotation of ninety degrees, seeing that the intensity of the transmitted light varies as the square of the sine of the angle comprised between the principal plane of the Nicol's prism and the plane of polorization. But this does not constitute a limitation of the instrument, as any degree of obscuration from perfect transparency to absolute opacity can be read upon the disc, if this is properly graduated over an arc of ninety degrees, to a rational scale on the basis of the above well-known law connecting the rotation with the percentage of light transmitted.

I must thank Mr. Sherman for recognizing that I was perfectly cognizant of the difference between determinations of turbidity and color, and that I only mentioned many of the methods employed with the object of showing that they had been improperly used.

I had not before heard of the colorimeter mentioned by him, but I have since read an account of it by Dr. Hollis in his paper on "Methods for the Determination of Color, and the Relation of the Color to the Character of the Water."

It is in no sense a turbidimeter, but simply an instrument for carrying out comparisons with any existing or other fluid standards rapidly and accurately, by varying the thickness of the latter. For this purpose it is the most ingenious and practical piece of apparatus I have yet seen described. The arrangement by which the light from two sources is brought into the same field of view only differs from that employed in my instrument in that two Nachet prisms take the place of one Wenham prism.

It will be seen that it thus in no sense trenches on the functions of the latter instrument, which has as an object the establishment of an absolute and rational photometric scale for turbidity estimates.

REPORT OF THE COMMITTEE ON UNIFORM STATISTICS.

[*Presented September 11, 1902.*]

BOSTON, September 10, 1902.

TO THE NEW ENGLAND WATER WORKS ASSOCIATION: —

Your Committee on Uniform Statistics presents the following report: —

During the year a considerable progress has been made in uniform water-works statistics. Perhaps the most important gain has been the adoption by the American Water Works Association and by the Central States Water Works Association of our form for summarizing statistics, so that all the water-works associations of this country have now adopted, and recommend their members to use, a single standard form.*

We are also pleased to report an increase in the number of water works reporting statistics in accordance with the standard summary, and greater uniformity in following the standard form. This appears to be the result of sending out blanks containing the headings of the standard summary.

The form endorsed nearly a year ago, which is a slight modification of the first form adopted by the Association, has proved generally satisfactory. We would, however, recommend a few slight changes, principally in the arrangement of items. The most important change proposed is the consolidation of the financial items into one table, instead of having separate tables for maintenance and construction, as heretofore. All the items of the summary as now used would be retained, and two or three new ones added; and it is believed that a seeker for information would be able to find the items he desired to use more easily in the proposed arrangement than in the one now in use. The proposed grouping is also in line, in a general way, with the scheme of the National Municipal League, and is thus a step towards uniformity with other societies.

The proposed new arrangement of the Financial Statistics, which was suggested by President Merrill, is as follows: —

* Since the above report was presented, the American Society of Municipal Improvements has also adopted the New England Water Works Association form. — ED.

RECEIPTS.		EXPENDITURES.	
Balance brought forward:		*Water Works Maintenance:*	
(*a*) From ordinary (maintenance) receipts,	$....................	AA. Operation (management and repairs),	$....................
(*b*) From extraordinary receipts (bonds, etc.),	....	BB. Special:	
Total,	$....................	....	
		..............................,	....
From Water Rates.		CC. Total maintenance,	$....................
A. Fixture rates, $		DD. Interest on bonds,	....
B. Meter rates, ...		(CC + DD), ...	
C. Total from consumers,	$....................	EE. Payment of bonds,	....
D. For hydrants, $...............		FF. Sinking Fund,	....
E. For fountains, ...			
F. For street watering, ...		*Water Works Construction:*	
G. For pub. b'ld'ngs, ...		GG. Extension of mains,	$....................
H. For miscel. uses, ...		HH. Extension of services,	....
I. Gen'l approp'n, ...		II. Extension of meters,	....
J. Total from municipal depts.,	....	JJ. Special:	
K. From tax levy,	....	....	
L. From bond issue,	....	...............:	
M. From other sources:		...., ...	
....,	$....................	KK. Total construction,	....
....,	$....................	LL. Unclassified expenses:	
		..............................,	....
		..............................,	....
		MM. Balance:	
		(*aa*) Ordinary, $...............	
		(*bb*) Extraordinary, ...	
		Total balance,	....
N. Total,	$....................	N. Total,	$....................

Disposition of balance, ...

O. Net cost of works to date . . . . $....................

P. Bonded debt at date . . . . $....................

Q. Value of Sinking Fund at date . . . . . . $....................

R. Average rate of interest, ... per cent.

Under the general heading of "Pumping" in the present form are two items, based on "Cost of pumping figured on total maintenance," reduced to "cost per million gallons" and to "cost per million gallons raised one foot." Being computed on the total expense of maintenance, this is not properly the cost of pumping, but rather the cost of supplying water, and should be applicable to gravity supplies as well as to pumping works. We therefore recommend that the items be transferred from Pumping Statistics to Statistics of Consumption of Water; that the cost per million gallons raised one foot (which would not apply to gravity works) be omitted, and that the two items appear as "Cost of supplying water, per million gallons, based on total maintenance (CC)," and "Cost of supplying water per million gallons, based on total maintenance, (CC) + interest on bonds (DD)." The former item should admit of comparisons between various works, while the latter, being dependent on the amount of bonds outstanding, would simply show the actual cost of supplying water under the particular circumstances.

When the Committee was continued at the last annual meeting, it was suggested that a form for summarizing statistics of purification works might be prepared and added to our present summary. Such a standard form seems very desirable, as there is at present a great lack of uniformity in the statistics kept at various purification works, and, indeed, at some very few data are kept. We have commenced the preparation of such a form, but there still remains a considerable amount of work to be done on it. We suggest that the Association authorize us, after preparing such a form, to give it a trial on several purification works before actually reporting it to the Association. This would not constitute an adoption of the form by the Association, but would enable us, at the next convention, to report with the form the results of its actual trial.

In brief, then, we report: —

First. A substantial gain in the adoption and use of our standard form of summary by the other water works associations and by water works.

Second. A recommendation of the adoption by the Association of a few slight changes in the standard form.

Third. Requesting authority to make trial use of the form for summarizing purification statistics which we now have in preparation

before reporting it to the Association, the result of the test, together with the form recommended, to be reported to the next convention.

Respectfully submitted,

JOSEPH E. BEALS,
GEO. F. CHACE,
J. C. WHITNEY,
M. N. BAKER,
CHARLES W. SHERMAN,
Committee on Uniform Statistics.

DISCUSSION.

THE PRESIDENT. Gentlemen, the report of the committee is now before you. We have with us this afternoon a gentleman who takes a great deal of interest in the subject of municipal accounting, and who, through his office as secretary of the Boston Statistics Department, and also as chairman of the Committee on Municipal Accounts and Statistics of the National Municipal League, is very well qualified to speak to us. I will call upon Dr. E. M. Hartwell to address us at this time.

DR. HARTWELL. *Mr. Chairman and Gentlemen of the Association,* — Perhaps I ought to explain my position. I came in here to hear the report of your committee, not expecting to speak. I do not wish to be taken for one who turns up wherever there is a chance to talk. I am reminded of an old black bath woman, an expert in a way on water matters, who had charge of the ladies' bath room at the White Sulphur Springs in Virginia. Her patience was somewhat tried by the ladies who were reluctant to bathe in her presence, and to such she used to say: "Don' you min' me, honey; it ain't no treat for me." [Laughter.] So while I am really interested in this subject I don't like to be thought too pleased at being called up to speak on it. That being understood, I am glad to express my thanks for the opportunity to tell you how this report has interested me. The report shows that the experience of your committee has been similar to that of the committee of the National Municipal League charged with the duty of drawing up schedules for the promotion of uniform municipal accounting and uniform municipal statistics. Our committee, like yours, has proceeded deliberately, and has asked to be continued so that we may test our schedules before recommending

their final adoption. It strengthens my confidence in our method of procedure to find that your method is of the same nature.

In general, the object of our committee is to establish a set of schedules to conform to the provisions of the municipal program of the National Municipal League, which was issued in 1899. In effect, the municipal program is a Municipal Corporations Act, intended to apply to all the cities in a given state, and to secure uniformity in administrative methods in the government of such cities. The legislature of Ohio has recently voted to establish a system of uniform municipal accounting, and is now considering the adoption of a general municipal act. The municipal program provides that the financial statistics of all cities, and the reports of city auditors or comptrollers, shall be made annually to a central office of control, for example, the state comptroller, in accordance with forms prescribed by the central office. Primarily our problem was to devise a set of schedules to conform to that scheme; at the same time we have sought to produce certain schedules which could be made use of now, inasmuch as for several years the Department of Labor at Washington has been called on under an Act of Congress to publish statistical tables relating to the financial operations of some one hundred and thirty cities of the United States. It is perfectly evident from a study of those tables that it is far from easy to reduce the material on which they are based to a common standard. Our committee, which has been at work for two years, has made two provisional reports, one at the Rochester meeting a year ago and a second at the recent meeting of the National Municipal League in Boston. Possibly we may be able to make a final report in May, 1903.

We have been fortunate in securing the experimental adoption of the principal schedule recommended in our report at Rochester. Thus the report of the auditor of Newton, Mass., for 1900, the report of the comptroller of Baltimore for 1901, and the reports of Mr. Harvey S. Chase (who is a member of our committee) on "The Accounts of Brookline, Mass., for 1901," and on the "Receipts, Appropriations and Expenditures of Boston for 1901," all contain a summary statement of receipts and expenditures drawn up in accordance with that schedule. Furthermore, the new scheme of bookkeeping and a new form of comptroller's report adopted by the city of Chicago at the instance of Messrs. Haskins & Sells, expert accountants of New York City, contain features recommended by our committee, of which Mr. Haskins is a member.

The Boston Statistics Department, of which I happen to be secretary, has published a study of Boston's receipts and expenditures for the fiscal year 1900–1901, consisting of seven tables based on the schedules recommended by our committee. You will find it published in Volume IV, No. 6, of the monthly "*Bulletin of Statistics*," of which I have a copy here.

In our second report to the National Municipal League, which is now in press, we have recommended a set of schedules embodying certain modifications suggested by the experience gained through testing the practicability of the schedules appended to our first report.

The two most characteristic features of our scheme are, (1) the separation of ordinary or maintenance and extraordinary or capital receipts and expenditures, and (2) the grouping of departmental receipts and expenditures under certain general heads, according to function; that is, General Government, Public Safety, — including Police, Fire, Health Departments, etc., — Public Works, Public Education, Recreation, and Art, etc. But I will not weary you by going further into the details of the scheme upon which we are still at work.

In the interesting report which your committee has just presented, the point has been made that the proposed statement conformed in general with the scheme of the National Municipal League — so it does. Yours is a consolidated statement showing ordinary (maintenance) receipts and expenditures on the one hand and extraordinary or construction (capital) receipts and expenditures on the other. If I may be allowed a suggestion, I would say that if the balance brought forward were divided to show how much was derived from ordinary and how much from extraordinary receipts, and the balance carried forward were similarly divided to show what was destined for the maintenance and construction accounts respectively, the schedule would conform very completely with our own. At least, that is my impression from such examination as I have been enabled to make through the courtesy of your committee.*

Thus far the committee of the National Municipal League has devoted itself mainly to the consideration of financial statistics. During the next twelvemonth we shall attempt to deal, to some extent, with other branches of municipal statistics, though we are well aware that in many branches chaos reigns at present. I devoutly wish there were a larger number of associations like this, — made up

* This was done in the form submitted, although the change had not been made in the copy shown to Dr. Hartwell. — Ed.

of men trained in the application of scientific rules and formulæ. If there were, the collection and presentation of statistical data in respect to important and interesting forms of municipal activity would yield much more satisfactory results than is usually the case.

There is no lack of people anxious and ready to compare cities with each other in respect to death rate, the per capita cost of parks, of charities and correction, fire protection, water supply, and the like. But such comparisons are apt to be misleading, because of the difficulty of securing an accurate standard of comparison.

Even in the comparatively simple matter of death rates, comparative statistics are open to grave suspicion, because the estimates of population in intercensal years are so often vitiated by guesswork and vainglory. I need not urge the need of scientific methods in estimating population upon you who have to estimate the growth of population as a basis for forecasting the future needs of your cities with regard to water works, sewers, etc.

I shall content myself with citing a single illustration.

Some years ago an elaborate and interesting paper comparing the principal cities of the country with respect to taxation, the cost of public works, etc., was presented at the meeting of the American Society of Municipal Improvements. The writer gave the population of Baltimore as 500 000 by "official estimate," for the year 1898. A few months later an article appeared in the *Charities Review*, in which Baltimore was compared with other cities in respect to the per capita expenditures for outdoor relief of the poor, and the population of Baltimore for 1898 was officially estimated (so the writer said) at 625 270. At the same time the Baltimore Board of Health calculated the death rates for 1898 on the basis of a population of 541 000.

I asked the health officer how he got his figure. He said, "Independently, on the same day, I sent to the two principal newspapers of the city and asked what their estimate of the population of Baltimore was. One said 540 000, the other 541 000, and I took 541 000." The United States Census in 1900 found a population of only 508 957. If in comparing cities in respect to the death rate, per capita cost of public works, and poor relief, the standard for a given year varies between 500 000 and 625 000 of population, we may well consider such comparisons as scarcely worth the paper that they are printed on.

Mr. F. H. Crandall. Mr. President, I move that the report of

the Committee on Uniform Statistics be accepted and adopted. By that I mean that their request and recommendations are endorsed by the Association.

(Mr. Crandall's motion is adopted.)

TWENTY YEARS AFTER. — A RETROSPECT.

BY ROBERT C. P. COGGESHALL, SUPERINTENDENT OF WATER WORKS, NEW BEDFORD, MASS.

[*Read September 11, 1902.*]

About two weeks since, I received a telephone message from the Secretary of this Association, asking if I would prepare remarks upon the topic which heads this paper, the same to be presented at this meeting. Finding that he had been disappointed in other directions in obtaining material for the program, I reluctantly consented.

I know that you would have been interested in a well-prepared review of the literary work contributed by the members of this Association since the date of its inception, over twenty years ago; but the time has been too brief for any attempt in that direction, and as most of you are familiar with the material which has been published, I shall have little to say touching that phase of the matter. I hope, however, to interest you in a sketch of reminiscences mainly drawn from the history of the Association from its earliest period down to the establishment of the JOURNAL in 1886.

The first question which may be asked is, "Who was the first to suggest an organization of this character?"

My reply is, James W. Lyon, then superintendent at Salem, Mass. While this story has hitherto been told, it never yet has appeared in the official publication of this Association, so it seems fitting that it should now be recorded.

As early as 1877 we find Mr. Lyon discussing the matter with neighboring superintendents. His idea then was the formation of a national association. He succeeded in arousing considerable interest, but his work did not immediately result in further development. During the next two years Mr. Lyon talked with every water-works official he happened to meet regarding the project. In March, 1879, he was induced to prepare a circular letter, which he mailed to every known water department in the United States and Canada.

The following is a copy of that circular: —

SUPERINTENDENT'S OFFICE, SALEM WATER WORKS,
SALEM, MASS., March 15, 1879.

Dear Sir, — Having for some time thought that the superintendents of water works throughout the country should have some way of becoming better acquainted with each other, and that it would be both pleasant and beneficial to all to have some kind of an organization and to meet in convention occasionally, to exchange ideas for the better management of the great interests we represent, I have ventured to propose the following questions to the superintendents and managing engineers of this country and the provinces.

First. Do you think it desirable to have such an organization?

Second. Is the project feasible?

Third. At what time of the year would it be best to hold the convention?

Fourth. Where is the best place to hold it?

Fifth. Would you probably attend such a convention?

Please answer, and add any suggestions that may tend to bring the subject in good shape before the fraternity.

Please address,

JAMES W. LYON,
Superintendent Water Works, Salem, Mass.

Mr. Lyon, in an address as President of this Association to the Worcester Convention in 1883, stated that four hundred copies of the circular were sent to various parts of the country, from which only seventy replies were received. He adds: —

"Of this small number there were those who thought the object a good one."

"Others replied that it was too comprehensive in taking in the whole country."

"There were others who thought that there was no need of such an organization."

"The lack of enthusiasm exhibited, together with the pressure of private interests, caused the abandonment of the project, although it was certain that if the project were carried into effect great good was sure to be the result."

A few years ago Mr. Holden, of Nashua, happened to meet Mr. Lyon at a Chicago convention of the American Water Works Association. At that time Mr. Lyon gave him a package of letters, which I now place before you to be deposited in the files of this Association. They are the replies which Mr. Lyon received in response to his circular. In looking them through I fail to understand how Mr. Lyon reached the conclusion stated, for to me they appear full of encouragement. It seems to me that if Mr. Lyon had

possessed more of the qualities of leadership, he would have experienced no trouble in effecting an organization at that time.

Let us briefly analyze these replies. The package contains fifty-six letters. Thirty-three are from localities outside of New England, almost every state east of the Mississippi River being represented. All are in sympathy with the project, and, with few exceptions, agree to be present at the first meeting. The range of location suggested for the first meeting was large. About one-half favored a "central location," most convenient to the largest number. There was the largest possible variation in ideas regarding the time, nearly an equal number favoring each season of the year.

One reply is worthy of reproduction. It is from one who later became prominent in the organization of this Association, and has remained one of its best known and strongest members. The language will be recognized as characteristic. He says: "I never have seen any superintendent but what I could learn something from, and any meeting of the kind you speak of would be a benefit to me; but as I might go to a convention of that kind to-day and have my head cut off to-morrow, I shall keep out. I will do my best to entertain any superintendent that may come here, and then I shall get the best of it, for if he is any way social he will be APT to tell me something that will be a benefit."

It is said that a wise man may change his mind. This is true in this case, for we all know that our dear friend Charles K. Walker, who wrote those lines, is lacking in neither wisdom nor good common sense. It is needless to say that he did not keep out, neither has he ever had his official head cut off.

In a few replies there appears the suggestion that it might be well to organize upon lines of limited territory. New England then contained one hundred and fourteen water departments. That territory might be the field of the work of one society, the Middle States of another, and so on. Then later a national society might be organized, of which the local societies would become branches.

Included in this list of replies were letters from W. L. Cameron, of Memphis, Tenn.; Ira A. Holly, of Burlington, Ia.; M. Donahue, of Davenport, Ia., and W. C. Stripe, of Keokuk, Ia. The enthusiasm of these gentlemen, once aroused, was not to be quenched. They heartily believed that the time was ripe for the organization of an association as proposed by Mr. Lyon's circular, and later we find them all prominently identified in the organization of the American

Water Works Association, which occurred at St. Louis, on March 21, 1881. W. C. Stripe took upon himself the responsibility of issuing the call for that gathering.

J. C. Briggs, of Terre Haute, Ind., took an active part in this organization. He was an enthusiast, as was shown a few months later, when we find him visiting several of the New England cities, and endeavoring by personal interviews to interest the department officials in the work so successfully inaugurated. His efforts were not fruitless. Interest in the project was easily secured, but the means of meeting the necessary expense in attending a convention at a distant center were not so clear to many. Indeed this phase of the question yet remains a serious obstacle to many in the attendance of our own conventions.

Such was the condition of affairs when three superintendents happened to meet, one bright winter's day, at Lowell, Mass. No previous appointment had been made; it simply happened by chance. On February 17, 1882, the writer took occasion to go to Lowell to acquaint himself with the inspection methods of the department of that city. For the first time he met Horace G. Holden, who then was the Lowell superintendent. During the morning Frank E. Hall, then in charge of the Worcester Water Works, called, on a friendly visit. Thus three officials met for the first time, all strangers to one another previous to that interview, but the friendships then formed developed into closer relationship with the passing years.

That day, while sitting around the dinner table at the Merrimac House, Mr. Holden called attention to Mr. Lyon's earlier efforts, and also to Mr. Briggs' more recent interviews in behalf of the American Association. A long discussion seemed to make clear the fact that New England offered a particularly good field for a helpful organization. While all were in sympathy with the work of the American Association, it seemed evident that the conditions and practices of the New England departments differed considerably from those of other regions of the United States. There was also the fact that there were such a large number of departments in a comparatively small territory that almost any of its centers were but a short distance from several water works. Thus several single-day meetings could be held in the course of the year, at which a good attendance could be secured, without much loss of time or burdensome expense on the part of the attendant. Such was the conclusion to which this discussion led, and after the dinner it was thought best

to attempt to enlist the interest of Henry W. Rogers, then superintendent at Lawrence, Mass. Accordingly Mr. Hall and the writer proceeded to Lawrence. Mr. Rogers had met Mr. Briggs, and was easily interested. It was agreed that the four gentlemen (Holden, Hall, Rogers, and Coggeshall) should constitute a self-appointed committee. Their first act was to write Mr. Lyon asking him to become a member of this committee and help in the work, to which he consented. The territory of New England was then divided into five districts, and each member of this committee took one of the districts for correspondence with the department officials located therein. All went to work, and a month later a comparison of returns was made. The success of the scheme seemed assured. The committee then decided to invite all interested parties within their districts to be present at a general meeting, to be held on April 19. I herewith present to the Association the original letter written by me at that time, from which the hectograph copies which were sent out were made.

OFFICE OF NEW BEDFORD WATER WORKS.
CITY HALL,
R. C. P. COGGESHALL, Supt *New Bedford, Mass.,* March 16th 1882

There is a movement being made to form an association of the water works managers of New England. This movement is endorsed by Mr Lyons of Salem, (who was the first to suggest the formation of such an organization) Mr. Holden of Lowell, Mr. Hall of Worcester, Mr. Rogers of Lawrence and others. This association is to meet once or twice a year in convention and exchange ideas. No doubt much profit as well as pleasure will be derived from these proposed gatherings. In order that the organization may be an assured success it is both necessary and important that there be a large attendance at a preliminary meeting which will be held on Wednesday April 19th The place of this meeting will be decided later, it will probably be Boston or vicinity. I am requested in the name of the informal committee mentioned above to extend an invitation to you to join the movement and to be present at the above named preliminary meeting. It is hoped that there will be a large representation of Registrars, Clerks, &c as well as Superintendents Should you find yourself interested we hope you will lend your influence by extending an invitation to be present at the preliminary meeting to all those whom you think would be interested.

Can you make it convenient to attend this preliminary meeting. If you wish I will advise you of the place of meeting as soon as it is decided

Yours truly

R. C. P. Coggeshall

FACSIMILE OF CALL FOR FIRST MEETING.

JAMES W. LYON,

First President of the New England Water Works Association,
1882–1883.

The suggested meeting materialized at Young's Hotel, Boston, on April 19, 1882. There were nineteen officials present, besides other gentlemen. As many will be interested to know just who were there, I give the list: —

Thomas C. Lovell, Fitchburg, Mass.
Joseph C. Hancock, Springfield, Mass.
Frank E. Hall, Worcester, Mass.
A. H. Martine, Fall River, Mass.
W. F. Cleveland, Brockton, Mass.
R. W. Bagnell, Plymouth, Mass.
Edwin Darling, Pawtucket, R. I.
Charles K. Walker, Manchester, N. H.
Henry W. Rogers, Lawrence, Mass.
Hiram Nevons, Cambridge, Mass.
Horace G. Holden, Lowell, Mass.
J. G. Tenney, Leominster, Mass.
S. E. Grannis, New Haven, Conn.
W. W. Hawkes, Malden, Mass.
Robert M. Gow, Medford, Mass.
James W. Lyon, Salem, Mass.
Robert C. P. Coggeshall, New Bedford, Mass.
James H. Hathaway, New Bedford, Mass.
J. J. Whipple, Brockton, Mass.
John L. Harrington, Cambridge, Mass.
W. W. Cross, Brockton, Mass.

Also present were: —

John C. Kelley, President National Meter Co., New York.
Lewis H. Nash, M. E., Inventor Crown Meter.
C. C. Cowpland, Agent Davidson Steam Pump Co.
Ex-Gov. James A. Weston, of Manchester, N. H.

Mr. Lyon was elected temporary chairman and the writer temporary secretary. Messrs. Darling, of Pawtucket; Nevons, of Cambridge; Hall, of Worcester; Martine, of Fall River, and Walker, of Manchester, presented suggestions regarding the development of the plan of organization. Messrs. Darling, of Pawtucket; Grannis, of New Haven, and Nevons, of Cambridge, were appointed a committee to prepare the draft of a constitution and by-laws, the same to be submitted to an adjourned meeting.

An attempt was then made to start a "topical discussion," but no one seemed inclined to talk. Here was a body of nineteen strangers drawn together by a common interest, but with one or two exceptions all were unaccustomed to public speaking. More or less embarrass-

ment was evident. There occurred at this time an incident which did much in making every one feel more at ease. Charles K. Walker was describing his experiences with wrought-iron, cement-lined pipe. He had just declared that without the slightest provocation it would burst once in every fifteen minutes, and he was giving further vent to his feelings regarding it, when the door opened and a fine-looking, elderly gentleman appeared. Mr. Walker stopped his remarks and said something like this : —

"Gentlemen, I wish to introduce you one and all to my friend Ex-Governor Weston, of Manchester, N. H. He is deeply interested in our work. The governor and I started life together as boys, but brains will tell every time. He has risen to the high honor of being governor of New Hampshire while I remain a miserable superintendent of water works."

The characteristic tone in which these last words were uttered provoked shouts of laughter, and conversation became freer.

The adjourned meeting was held at Young's Hotel, Boston, on Wednesday, June 21, 1882. There were twenty-five officials present, Desmond FitzGerald, of the Boston Department, and Albert S. Glover, then water registrar of Newton, being among the newcomers. The committee appointed at the previous meeting presented the drafts of the Constitution and the By-laws. These were taken up in debate, a few changes made, and then adopted, after which the following officers were elected under the provisions of the constitution : —

President : James W. Lyon, Salem, Mass.

Vice-Presidents : Charles K. Walker, Manchester, N. H. ; Hiram Nevons, Cambridge, Mass. ; Edwin Darling, Pawtucket, R. I. ; H. L. Schleiter, Meriden, Conn.

Secretary : R. C. P. Coggeshall, New Bedford, Mass.

Treasurer : Edwin Darling, Pawtucket, R. I.

Executive Committee : The above named, with Frank E. Hall, Worcester, Mass. ; A. H. Martine, Fall River, Mass. ; J. G. Tenney, Leominster, Mass.

Financial Committee : J. Warren Cotton, Cambridge, Mass. ; Horace G. Holden, Lowell, Mass. ; Phineas Sprague, Malden, Mass.

That was twenty years ago. It seems as if it were yesterday. Through memory's eye I see the space before me alive with the faces of those who were present and who since have joined the silent majority. There was Cotton, the genial registrar of Cambridge ; Nevons, the able superintendent of the same city ; Darling, the energetic superintendent of Pawtucket ; Lyon, the first President of the Association,

PLATE II.

FRANK E. HALL,

President of the New England Water Works Association,
1883-1884.

and Rogers, the well-equipped but exceedingly modest superintendent of Lawrence. Then there were Schleiter, of Meriden, and Sprague, of Malden. All were prominent at that time, but now their voices are silent.

At a meeting held the following October, at Salem, there appeared for the first time the face of one of the sweetest characters I ever have met. He proved to be a strong addition to our forces, and was of great assistance in the early development of the Association. He later honored the Association by filling positions of trust, and finally he became its president for the year 1890–91. Of course I refer to Albert F. Noyes, whose tragic death in the Park Square Station, of this city, on October 12, 1896, we have never ceased to mourn.

The Association seems to have been slow in its development during the first year. The President, Mr. Lyon, was a large man, exceedingly amiable and having great interest in the work. But he was deliberate and ponderous in his mannerisms, and did not seem to possess the faculty of inspiring others. The writer was thoroughly "green" concerning best methods of conducting the secretary's work. So I always have thought that others possessing greater experience could have accomplished more that year than did we. One thing is certain, — the members became well acquainted with each other, so perhaps there was more of a solid foundation laid than at first sight appears.

At the second convention, at Worcester, in 1883, Frank E. Hall was elected President, and he proved an admirable choice. At that time the membership had reached forty-three. Not a large number, you will say, but the leaders of that day did not dream of a society of ambitious proportions, with its well-equipped accessories, as it now exists. Their ideas had rather the opposite trend, — a club of select membership, modest in numbers; the meetings to be more of the nature of social and informal gatherings, affording opportunities for the comparison and discussion of personal experiences.

Walter H. Richards, William R. Billings, George A. Ellis, and Charles H. Baldwin were present at this meeting, and took active parts in the proceedings. Later each of these gentlemen did an immense amount of work in our interest.

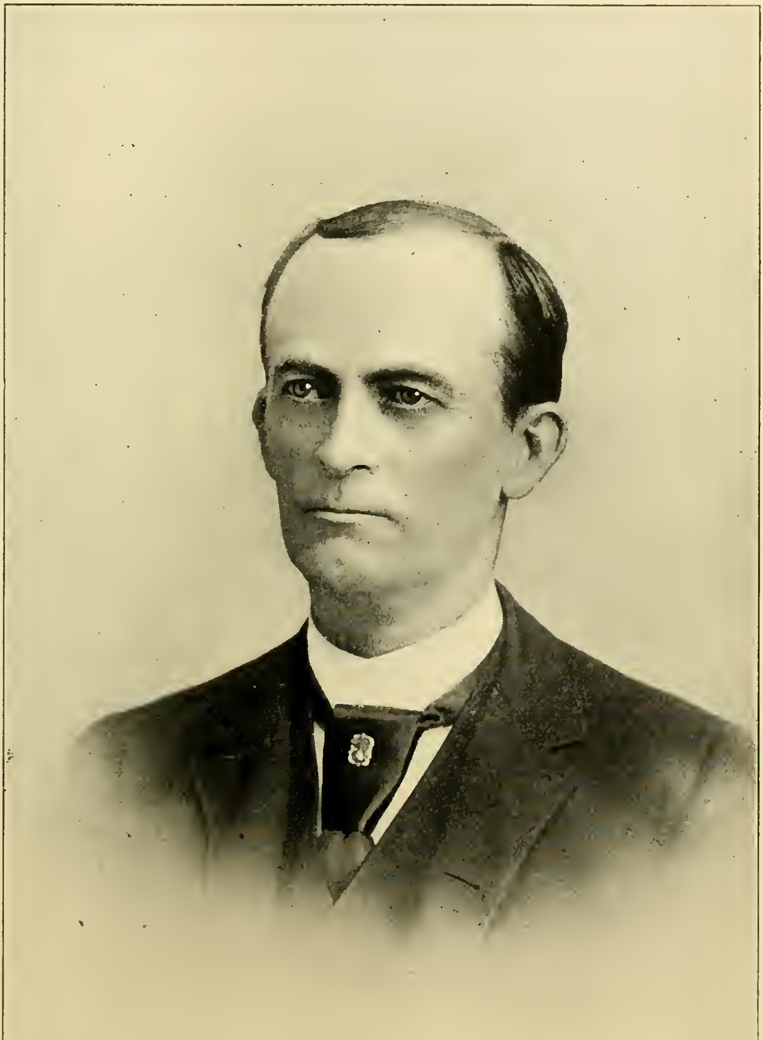
If you had been present at that convention you would have heard Darling (he was always energetic and positive in his discussions) maintaining that there were no hidden leaks upon his pipe system,

and that the only leaks that gave him trouble were those around the faucet. Nevons quickly took issue with this statement. He had given a great deal of attention to night inspection of the Cambridge pipe system, and had discovered many hidden leaks. Darling was an earnest advocate of the "meter" system, so he had the best of it when this question was considered, while Nevons hoped that the general application of meters to prevent waste of water would never come. He pleaded for a well-organized system of house-to-house inspection, which he thought would be more effective. In later years he was converted from that opinion, in company with many others.

The following fall the Association was entertained at Pawtucket, R. I. After sight-seeing about the town, a steamboat was taken for one of the shore resorts down the bay, where an excellent clambake was served. Many of you will remember the fine display of fire streams which Darling made as the boat passed through the draw of the India Point Bridge. We all passed under an arch of living water.

The third annual convention was held in Lowell, Mass., on June 19 and 20, 1884. The officials had worked hard, and they were rewarded for their efforts in having a convention which showed advance in the quality of the papers presented. Two especially able papers were read, one by W. H. Richards, of New London, and the other by H. W. Rogers, of Lawrence. The former attracted considerable attention outside the ranks of the society, and has reappeared many times in various publications. It was at this convention that William B. Sherman, one of the most conscientious workers of our early years, unfolded his scheme for the exchange of sketches. His plan called for an agreement on the part of each member to bring to each annual convention a sufficient number of sketches of an idea or device to supply all other members who were prepared to exchange. Sherman worked hard in creating a sentiment in favor of this scheme, and for a number of years it was practiced quite successfully. But a few years bring many changes. A large proportion of the old membership drops out of sight, and a constantly increasing number of new individuals join the ranks. The idea did not appeal with sufficient force to the newcomers to induce them to continue the work. It therefore gradually dwindled. Finally there came a meeting at which very few sketches appeared, and the scheme was then dropped. If our membership only could realize what an im-

PLATE III.



GEORGE A. ELLIS,

President of the New England Water Works Association,
1884–1885.

mense amount of information could be imparted by this simple process, they would not have allowed the practice of Sherman's most excellent scheme to have faded completely out of sight.

No one present at this meeting will ever forget the wonderful hydraulic display which occurred while the morning session was being held in the parlor of the St. Charles Hotel. An unusually severe thunderstorm occurred, which broke up the meeting. Presently a horseless carriage appeared upon the street and passed the hotel. There was no driver to guide its course. It moved very like an automobile. It was propelled by the power of the violent wind and rain. Whence it came or whither it went we never knew. Neither can we forget the good-natured bantering which occurred later in the day at Tyng's Island, between Col. A. A. Hagget, of Lowell, and Charles F. Chickering, of Pawtucket, R. I. And also we remember our worthy member who lost his hat, and his frantic attempts to regain the same, directly in front of Mayor Donovan, who then was addressing the convention in the dining-room of the St. Charles Hotel. Among the new faces which appeared at this meeting were those of George E. Batchelder and Lucian A. Taylor, both of Worcester.

At this convention George A. Ellis, then city engineer and water registrar of Springfield, was elected President. Mr. Ellis had secured an excellent reputation throughout the country by reason of his original work in hydraulic investigation. You are all familiar with his little book relating to the flow of water in pipes and fire streams. It then had been recently published. He was very prominent in our affairs during the period of which I now am writing. Shortly after, his professional work called him to a distant part of the country, and we were the losers thereby. At the same meeting Albert S. Glover, then water registrar of Newton, superseded the writer as Secretary. With these two able pilots at the helm, the Association made a rapid advance, and the next year occurred the most brilliant social event which this society has ever witnessed.

During the following fall the Association was entertained by the city of Newton, with sightseeing during the day and a banquet at Hotel Vendome, Boston, in the evening.

The following year occurred the joint meeting of this Association with the American Water Works Association, which held its annual session at Young's Hotel, Boston, in April, 1885. Previously a committee had been appointed to arrange a program of entertain-

ment for the visiting delegates of the American Association. The members of this committee were, Frank E. Hall, chairman; Albert S. Glover, secretary; J. Henry Brown; A. H. Howland; Albert F. Noyes; Wilbur D. Fiske; Jason Giles, and Charles H. Baldwin. While each member should receive a full share of the credit due the committee, I wish to make special mention of two of these names, because the committee was saved the embarrassment of planning in the dark by reason of their personal guarantee to raise the financial means necessary for the execution of the scheme. I refer to Jason Giles, who was the manager of the Chapman Valve Manufacturing Company, and Wilbur D. Fiske, who was agent for the George F. Blake Pump Company. Both were greatly interested in the welfare of the Association in those days, and did much personal work in promoting its interests. Fiske was a great joker. He possessed a most vigorous activity, and was always sure to have a crowd around him. Unusual demonstrations of merriment could always be heard when he appeared upon the scene.

The committee succeeded in collecting a fund of nearly twenty-five hundred dollars, all of which was expended in the execution of a well-planned program of entertainment. I don't ever remember passing a week in which every detail of a printed schedule was better executed. It was a continuous succession of festivities, and I remember that one of our best-known members afterwards told me that for two weeks after the close of the convention he had difficulty in keeping awake all day. It certainly was a most enjoyable week for all of us, and I think it was equally so for the visitors whom we entertained. Colonel Gardiner, of New Orleans, was the president of the American Association at this time, and J. H. Decker was secretary. They were very happy men during that week, and so were all of us. At the close of the convention Peter Milne, of Brooklyn, succeeded Gardiner as president of the American Association. Later he became secretary, which position he held until his death a few months ago.

The visiting delegates to the convention came as strangers to most of us. They returned to their homes with a host of new friends, and there are many strong ties of friendship to-day which date their origin from the time of this gathering.

The entertainment program included visits to places of interest, sometimes two or more parties going in different directions, and all in perfect harmony. The star event of the occasion, however, was the

PLATE IV.

Photo. 1902.

ROBERT C. P. COGGESHALL,

President of the New England Water Works Association,
1885–1886.

"Duty Test of the American Water Works Association by the New England Water Works Association." It seems that Colonel Gardiner had asked in open convention in a previous year, "What is perfect duty?" referring, of course, to pumping engines. This test was in answer to his question, but on rather different lines from those to which his inquiry had been directed. If any pump had been necessary upon that occasion it would have been a stomach pump, for cases in which Nature had failed to perform her functions.

The menu was printed in an elaborate portfolio containing many technical phrases used during boiler tests, and illustrated with humorous sketches. The frontispiece of the menu was adorned with the motto, "'What is perfect duty?' L. H. Gardiner." I believe that the conclusion reached by this duty trial was that it consisted in attending to business, as exemplified by the illustrations on one side of the menu, and in not forgetting the good things of life as shown upon the remaining pages.

This elaborate function was held at Young's Hotel on the evening of April 21, 1885. It was elaborate in every sense of the word. The food, music, flowers, and the speaking which followed were all of superior quality. It was long after midnight when the benediction was pronounced. Quite a number of us had adjoining rooms which opened into each other. Of course we had to talk the event all over. About this time Fiske appeared with two colored individuals carrying pails containing liquid refreshments packed in ice. He was accompanied by another member, who proceeded to give us an astonishing dissertation on pipe laying. How we laughed! He was very lengthy, and we were both glad and frightened when he finished and left us, — glad that the end had come, and frightened at the way in which he went down stairs. As Fiske afterwards expressed it, the sound was similar to that caused by a large safe sliding down stairs and striking the floor below.

Glover had arranged to secure a fine report of that "Duty Test" banquet. You can imagine his consternation a few days later when he found that the reporter had lost every scrap of his notes concerning the event. Glover then went to work. He collected every newspaper report obtainable, and then with the aid of different memories the report was written as it now appears in the transactions of 1885. This episode, however, proved to be a blessing in disguise. More care was hereafter exercised in the selection of a reporter. This resulted in the discovery of Mr. James P. Bacon,

who sits before me, and who from that day to this has been constant in our service. His work, to say the least, has always been extremely satisfactory. A meeting of the Association would hardly seem complete without his presence.

In the long list of candidates who were elected members at this time the following names appear: William F. Codd, Dexter Brackett, Willard Kent, Wilbur F. Learned, F. H. Parker, and George A. Stacy.

Two months later (June, 1885) the fourth annual convention was held at Springfield, Mass. The writer succeeded George A. Ellis as President, and Albert S. Glover continued as Secretary. At this meeting Albert F. Noyes presented an elaborate paper on cast-iron pipe, and a lively discussion followed. This subject has been a perennial source of discussion from that day to this. The same may be said concerning "Service Pipe." Whenever short of material for our programs the introduction of either of these topics has been sure to provoke interesting debate.

At this same convention Mr. Billings and the writer presented a plan to secure uniformity in the presentation of the annual reports. This is another topic which has attracted considerable attention ever since.

Other papers presented were: "Relating to the Use of Tanks in Supplying Water-closets and Hot-water Boilers," by William R. Billings, and "Flushing Street Mains," by J. Henry Brown.

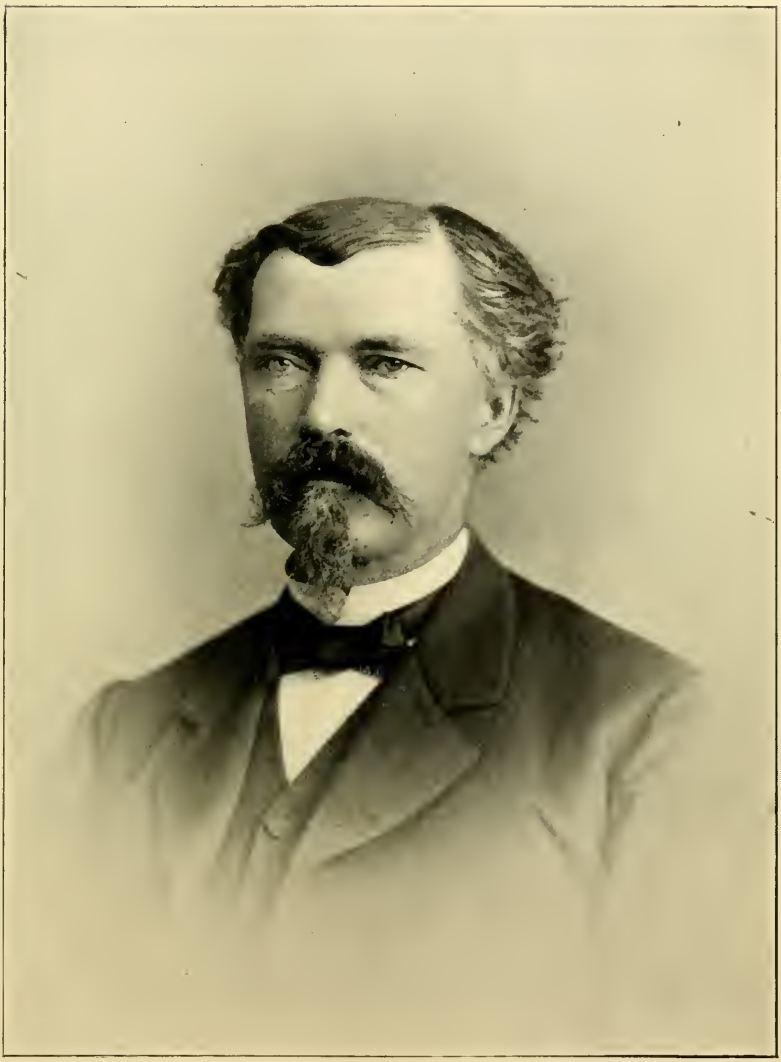
The most important act which occurred during the writer's administration was the development of the plan of the quarterly JOURNAL in its present form. It was Glover who conceived the idea, and I well remember when he first unfolded his plan and displayed figures to show that financially the scheme could be made a success.

The materialization of the plan for the publication of the JOURNAL required certain changes in the Constitution. This matter was referred to a committee who reported to the New Bedford convention in June, 1886, when the suggested changes were adopted. The positions of Senior and Junior Editors were created, and an increase in revenue was provided for by reëstablishing the status of the associate membership.

The first number of the JOURNAL appeared in September, 1886, and contained the proceedings of the New Bedford convention. It has continued to appear regularly each quarter up to the present time.

At the New Bedford convention more new faces appeared. There

PLATE V.



HENRY W. ROGERS,

President of the New England Water Works Association,
1886–1887.

were Patrick Kieran, Frank L. Fuller, Joseph E. Beals, M. M. Tidd, Phineas Ball, and William M. Hawes. The last three remain with us in memory only. Phineas Ball was a well-known pioneer water-works engineer, and a good one, too. He had been present at previous meetings, and now became a member of the Association. He had a genial and kindly nature, and made friends in every direction. I well remember the deep interest he took at that convention in the discussion which followed Desmond FitzGerald's excellent paper on "Rainfall." Mr. Ball and David B. Kempton, of my own city, were old friends (Mr. Kempton was a familiar figure at our conventions), and I used to enjoy hearing them rehearse former events.

M. M. Tidd you will remember as an accomplished engineer. He gave us all a great deal of inspiration and help. He had only one arm, and yet he was one of the best draftsmen I ever met.

William M. Hawes was the wit of the Association for many years. He was ready to discuss any question which came up. What a happy, jolly individual he was, and what faculty he possessed for putting every one about him in a good humor. How we sympathized with him in his long, painful illness, and when the end came we mourned his loss. When he made his bow to the Association at New Bedford, water meters were under discussion. He said that the perfect meter had not been invented; that he thought it would be like the perfect man, — just as he gets perfect he up and dies. The millenium will come with the perfect meter, and then we will have no use for it. He closed his remarks with the recital of a humorous poetical confession of a wicked water meter, which convulsed the whole audience.

At this convention, in addition to FitzGerald's "Rainfall" paper, George A. Ellis contributed a paper on "Discharge of Mains as Determined by Pressure Gages." Col. J. T. Fanning presented a paper on "Pumping Machinery," and Dexter Brackett, one on "Wastes of Water." Besides these there were many topical discussions.

The Association had its headquarters at the Parker House in New Bedford. After the evening session of the second day the rooms were filled by a crowd which was in no hurry to woo the sleepy god. A number being of a musical turn of mind took to singing the popular songs of the day. Perhaps to outsiders it sounded more noisy than musical. Anyhow it disturbed some of the inmates of the house, one of whom got up and sought the aid of a police officer

whom he found outside, surveying the windows from whence the sound issued. The disturbed lodger urged the officer to go in and stop what he termed an unmitigated nuisance.

"No, you don't," replied the officer, "I know my business. The mayor 's in there."

The next day, upon the excursion boat, in passing down the bay you could have heard Fiske pointing out the old Revolutionary Fort Phœnix to the crowd, and endeavoring to convince them that it was there that Ethan Allen demanded the surrender in the name of the great Jehovah and the Continental Congress. Upon a protest being made by a member from Vermont to the effect that the event described had occurred near his home, Fiske replied, "Well, I 'll postpone the rest of this story and continue it when we have a convention in Vermont."

At the closing session of the New Bedford convention, Henry W. Rogers became President, Albert S. Glover continued as Secretary, and William R. Billings and the writer assumed the duties of editors of the first issues of the JOURNAL.

The next year (1887) the annual convention was held at Manchester, N. H., at which place I resumed my former position as Secretary, which office I continued to fill until January, 1895. During this period the annual conventions were held in the following places: —

1888, Providence, R. I.
1889, Fall River, Mass.
1890, Portland, Me.
1891, Hartford, Conn.
1892, Holyoke, Mass.
1893, Worcester, Mass.
1894, Boston, Mass.

The Presidents with whom I served were: —

1887–88, Edwin Darling.
1888–89, Hiram Nevons.
1889–90, Dexter Brackett.
1890–91, Albert F. Noyes.
1891–92, Horace G. Holden.
1892–93, George F. Chace.
1893–94, George E. Batchelder.
1894–95, George A. Stacy.

The Senior Editors of the JOURNAL with whom I was associated were: —

Prof. George F. Swain, two years.
Desmond FitzGerald, one year.
F. H. Parker, one year.
Dexter Brackett, four years.

The Junior Editors were: —

William R. Billings, two years.
Albert S. Glover, two years.
Walter H. Richards, five years.

Brackett, Richards, Glover, and Billings all did an immense amount of detail work, and the Association profited by their conscientious efforts.

This Association had published over one hundred and fifty important papers up to the time I resigned the secretaryship in 1895. There had also been more than that number of topical discussions.

With the New Bedford convention, in 1886, I close this series of reminiscences. Many members of prominent standing, familiar to you all, have not been mentioned in this paper simply because their connection with the Association dates from a later period. The list is a very long one, and cannot with justice be lightly entered upon in a brief survey; so it appears better to refrain from any attempt at this time. There are those who have done what they could, and done it well, and the Association has been a gainer thereby. Proper credit should and will be ascribed to them in a future review of the period of time in which they worked.

One word regarding the JOURNAL. In 1893 a full index of all our previous publications was published. This was the work of Henry N. Ogden, C. E., and Dexter Brackett. It has occurred to me that the revision of that index up to and including the volume now in publication would be a production which would be appreciated by the frequent readers of our society publications.

I have heard the charge made that our Association has become more of an engineering club than a water works association, and that technical productions outweigh the practical. Is there any foundation for this statement? I think not; for I am not aware that the needs of the practical worker have ever been overlooked. That a larger number of practical papers would be acceptable goes without saying; but it is exceedingly difficult to induce the average practical worker to relate his experience. He likes to listen and absorb, but dislikes to talk; while on the other hand it is compara-

tively easy to secure the production of the well-trained student. This is the reason why it is difficult to always obtain a proper balance for an ideal program. We will all agree that the interests of the practical worker should be jealously guarded. He should be supplied with plenty of material each year. But the progressive worker cannot and will not stand still. You never knew a broad-minded practical worker of limited education but that he regretted his lack of technical training. Such a man is bound to press forward. He will absorb all he can, and the time soon arrives when his thoughts pass from elementary stages to more profound considerations.

Papers are occasionally presented the technical portion of which is too abstruse to secure the appreciation of the majority of our attendants. While such papers have their proper mission, it is better in the interest of best results that the speaker confine his remarks to limits within the range of all his listeners. We are very fortunate in having in our membership a few who rank high in their special work. They are constantly delving in pursuit of nature's secrets ; and when rewarded by success in their undertakings, they come here and tell us about it in language so simple that every listener comprehends the truth that is uttered. No one ever complained that he could not understand every word of Prof. William T. Sedgwick's admirable addresses to this Association ; and he always secures the delighted attention of the practical worker. The scientist that follows this plan is the true educator, and makes an ideal member of such a society as this. He interests the practical worker, and is sure to unconsciously influence his future thoughts. The worker in turn gladly aids him to new observations and the securing of data for new investigation. By such a process as this, the ideas of the worker will constantly aspire to higher standards.

In conclusion, the question may be asked, After twenty years, what? I think we can point with pride to the monument of literature which the members of this Association have gradually erected during these past twenty years. There it stands upon your shelves in almost as many volumes. No question is likely to arise in the practice of any official but that information pertaining to the same does not appear somewhere in its pages. Those volumes are among the best of reference books which every superintendent should have before him in his daily work. It needs no further encomiums. The work of its preparation has been done in the past by faithful and willing hands, and I am sure this will continue.

In considering the future of our Association from the present point of view, we see a well-equipped headquarters in Boston; the financial aspect in healthy condition; the absence of all jarring discord, and an interested membership who attend our meetings. As long as this condition continues it does not appear worth while to entertain any concern regarding what the future may have in store.

APPORTIONMENT OF CHARGES FOR PRIVATE FIRE PROTECTION AND THE MEANS OF CONTROLLING THE SUPPLY THERETO.

[*Reports of Committee and Discussion, September 11, 1902.*]

F. H. CRANDALL, C. K. WALKER, J. C. HAMMOND, JR., B. I. COOK, E. V. FRENCH, H. A. FISKE, AND JOHN C. CHASE, *Committee.*

The President called on Mr. Crandall for the Committee's report.

MR. F. H. CRANDALL.* As was understood when this Committee was appointed, Mr. President, some of its members held diametrically opposed views in regard to at least two of the matters involved, namely: First, as to who should pay the cost of private fire protection, and, second, as to the question of limiting the sizes of services permitted. We are obliged to report to-day that we are unable to agree, and probably never will be able to agree, on these two points. Three members of the Committee, Mr. Walker, Mr. Hammond, and myself, submit the following statement: —

Report of Messrs. Crandall, Walker, and Hammond.

Three members of your Committee, to whom was referred the matter of apportionment of charges for fire protection and means of controlling the supply thereto, would respectfully report that we find the opportunities for taking water without the knowledge of the water department, afforded by the presence of private fire pipes, are frequently taken advantage of; that furnishing private fire protection merits compensation; that the compensation, however, should not be such as to discourage the use of automatic sprinkler systems; that securing assurance of the use of private fire pipes for such purposes only is a matter of small expense and may reasonably be required.

We would recommend that, provided trustworthy evidence in regard to the use of the service and reasonable remuneration for the protection afforded be furnished, such applications for private fire services as will not unwarrantably jeopardize other interests be granted.

MR. EDWARD V. FRENCH.† As Mr. Crandall says, our Committee have had different ideas, and we have not been able to agree even on two reports. We have had a most interesting dis-

* Superintendent of Water Works, Burlington, Vt.

† Inspector Associated Factory Mutual Insurance Co.'s, Boston, Mass.

cussion in the Committee, and those of us who differ from Mr. Crandall feel that he has gone just as far as he can in the matter with the view which he takes of the underlying principles of the whole thing, and we think he has shown a very excellent spirit in trying to get us together. I think if we had had more time, or, rather, if we had lived nearer each other so we could have had more frequent meetings, we could have agreed on some sort of a report; but, although we have had a great deal of correspondence, we have not succeeded in having meetings where we could all be present, except in one or two instances. I think we have never had a really full meeting, but we have discussed a good deal of matter which has been interesting, and I think we have all learned something; I am sure I have.

Our feeling was, then, that we could not do better, as long as we could not agree and as long as the matter had been deferred so many times, than to bring in our several ideas in the briefest form we could, and to say that in the most friendly spirit we had agreed to disagree and to put the facts before the convention and let the matter stand there. It may be that some further work can be done that will be of interest, and I think we are not very far apart now in the final result, our real difference coming in the fact that we feel that there is an underlying principle which gives a man a right to certain things, which Mr. Crandall and the other two gentlemen feel does not exist; and although the actual amount that Mr. Crandall wants to charge for the private fire service is small, and perhaps not appreciably larger than the user would be charged under the scheme that we have in mind, we felt that nothing was to be gained by covering up what seemed to us to be the elementary principles that underlie the whole thing, — questions of right and justice. And, as I say, our differences are wholly of a friendly nature and are wholly based on our different conceptions of the thing.

Now, we have put together a brief report which, if I may be allowed, I will read. This report is agreed to by Mr. Fiske, Mr. Cook, and myself. I think Mr. Chase will have something to say later which will show where he differs a little from all the rest of us. Our report is as follows: —

Report of Messrs. French, Cook, and Fiske.

Investigations and experiments made by your Committee have resulted in the following conclusions: —

First. Taking the country at large, water is taken somewhat frequently from private fire pipes for manufacturing and miscellaneous uses without the knowledge of the water departments.

The majority of such takings are not with deliberate intent to defraud the water department, but from a lax view of the rights in the case. Instances of intentional stealing, even to the extent of making concealed taps, are, however, not uncommon.

Second. Private fire protection is a benefit to the general public, because it greatly lessens the chances of a partial or total destruction of a prosperous manufacturing industry, which always means a loss of wages to operatives and sometimes a loss of the industry to the town. Further, fire allowed to gain headway in a large plant may spread and do great damage to surrounding property.

The effectiveness of private protection is largely due to the automatic sprinklers which cover every part, even to the most obscure corner, and stand ready night and day to put water on a fire the instant it starts.

Third. Water supply systems are almost universally laid out to furnish water for extinguishing fires as well as for domestic and manufacturing uses. A manufacturing concern, therefore, has a right to water without charge for extinguishing fires, the same as any other taxpayer. If then, the manufacturing concern puts in protection and desires to use public water in this private system for fire purposes because the public water can be used more effectively in this way, it is usually reasonable and right to allow it, providing absolute assurance is secured that water is not used for any other purpose. To allow this entails no extra cost to the public whatever, and absolutely lessens the calls which a plant makes on fire and water departments.

Fourth. Plants having private fire protection should pay all cost for such equipment, all the first cost for connecting to the public mains, and a yearly charge, ample to reimburse the public water department for all reasonable supervision of their fire pipes, such as to read and keep in repair any detecting devices which may be provided, and any other similar expenses.

Where a protected plant desires a better water supply than that furnished to the average taxpayer, considering relative values, it is right and proper that a part, if not all, of the cost of the additional mains needed should be paid for by the protected risk, the conditions in each case determining what is just.

Fifth. There are at present a number of ways by which assurance can be secured that private fire pipes are used for fire purposes only. It is considered that this branch of the investigation could be extended to advantage. The following methods have been examined with results as given: —

(*a*) Ordinary meters are not satisfactory from the possibility in many types of serious obstruction to the flow and from the fact that large size meters are frequently not sufficiently sensitive to detect the smaller drafts.

(*b*) Hydrants, sprinkler valves, and all other outlets of the fire system may be sealed, and a penalty provided for a broken seal which cannot be satisfactorily explained. Such sealing gives considerable protection, but is not positive guard against the unscrupulous taker, and it requires regular supervision on the part of the water department. The general extension of sealing throughout fire systems would be considered rather undesirable by the underwriters, from the tendency it has to take the responsibility for the private fire apparatus away from the mill people, thus encouraging them to rely more and more on the public department, where experience is believed to indicate that a good private fire brigade is always desirable in a large manufacturing property.

(*c*) A $\frac{5}{8}$-inch by-pass may be provided around the main gate where the fire service enters property having private protection. A water-works official can quickly slip a meter into this connection, shut the main gate without

notice, and thus instantly detect a flow of water. This method gives no constant watch, but, in some cases where conditions will permit, may give the water-works superintendent all the means he needs to feel reasonably sure as to the use of private fire pipes.

(*d*) Proportional meters consisting of a weighted check valve with a small meter in a by-pass around it can detect very small flows, and will give good results where the fire services are used for fire purposes only, and where any other use which the detector may indicate may be considered a violation of the contract, resulting in a penalty. This device, it is believed, has possibilities of further development into a more convenient and serviceable piece of apparatus.

(*e*) Various other special devices and inventions have been partially considered, but need more study before a report of value can be made.

Sixth. Data as to the layout, use, value, and cost of private fire protection were suggested by the questions submitted to the Committee. The following facts are presented: —

(*a*) Extensive private fire systems are laid out by the engineering departments of insurance associations.

(*b*) The simplest arrangement of piping is always desired.

(*c*) The general custom is to absolutely separate the fire pipes from those supplying water for manufacturing and similar purposes.

(*d*) Outside gates with indicator posts are provided on connections going inside of buildings, to permit shutting off water in case of breaks.

(*e*) The requirements of the water department as to the plans of private piping, uses of water, notice of tests, etc., should always be strictly followed by the protected risk.

(*f*) A yearly test of the capacity of public water, to ensure that all is in good condition, gates open wide, etc., is usually desired by the underwriters.

(*g*) Private protection usually costs the owners from three to five per cent. of the total value of the property which could be destroyed by fire. A $300 000 plant, therefore, requires from $9 000 to $15 000 for full equipment.

(*h*) From $100 000 000 to $200 000 000 is annually destroyed by fire in the United States, and private protection is the best means of reducing this loss.

(*i*) Records for the year 1900 from a group of protected risks manufacturing cotton and woolen goods, paper, and general metal work, with an aggregate value of $900 000 000, show that only 450 fires were reported with a total loss of $555 000. Three hundred and seventy-nine of these fires caused a loss less than $1 000 each; 59 less than $10 000, and 12 a loss of over $10 000. In the case of the 12, the large loss was due to some deficiency in protection or some accident.

We suggest that a committee be appointed to continue the subject and investigate means whereby assurance may be had that private fire pipes are used for fire purposes only, and report to the Association at some future meeting. We also suggest that such committee be requested to confer with the American Water Works Association, the National Fire Protection Association, and any other similar organization which may desire to coöperate on this subject, in order that the experience of all may be obtained and that any further action may be uniform and harmonious.

SEPTEMBER 11, 1902.

MR. WASHINGTON PAULISON.* I move, Mr. President, that Mr. Crandall's report be received and approved by the Convention.

MR. FRENCH. I think Mr. Chase ought to be heard from before we take any action.

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*Superintendent of Water Works, Passaic, N. J.

THE PRESIDENT. We should be glad to hear from Mr. Chase as a member of the Committee.

MR. JOHN C. CHASE.* Mr. President, I find myself in the rather unenviable position of not being able to agree upon all points with my esteemed associates on either side of the fence, but I do not know that my position is much worse than that in which a distinguished justice of the United States Supreme Court found himself in regard to the insular decisions, which some of you may have heard spoken about more or less last winter. On the fundamental proposition I do not differ materially from that held by the water-works members of the Committee, and I am not able to endorse all the views of the other members; but I have very briefly reduced to writing what I have to say, and it is as follows: —

Report of Mr. Chase.

It appears to be beyond question that there is a gross misuse of fire service systems, but it is only fair to assume that in many cases the unlawful use is due to a low standard of morality in regard to corporate rights in water rather than wilful larceny.

The municipality having assumed the responsibility of providing a water supply for fire protection, the expense of the same being uniformly distributed by taxation among those benefited, I hold that those who, at their own expense, equip their establishments with additional means for the more effective prevention or suppression of fires should not be subjected to any charge, except what may be required to cover the expense of the supervision needed to make certain that no unlawful use of the equipment is made. I do not consider that the benefit derived by the consumer in the way of decreased insurance premiums, or the indirect gain to the community by preventing a fire has anything to do with the question at issue. The generally understood custom credited to railroad corporations of "putting on all that the traffic will bear" should have no place in water department management.

I believe that all expense of connections and necessary indicating devices to insure that no improper use is made of the fire service pipes should be borne by the consumer, also any changes in the street mains made necessary by the requirements of the system to be installed. The unlawful use of the pipe system should be punished by a deprivation of its benefits.

THE PRESIDENT. Gentlemen, this report has come before the Association in a very interesting form, and it is now before you for your discussion and action. I trust it will receive careful consideration at your hands. We should be glad to hear from Mr. Paulison now.

MR. PAULISON. We have furnished water to manufacturers to be used only for the extinguishment of fires, and we have relied upon

* Civil Engineer, Derry, N. H.

them to use it for that purpose and that only; but we have found in many cases that they used it for other purposes. We have put on meters and we have found that they worked satisfactorily. Now, inasmuch as we charge the city for hydrants, I don't understand why we should allow manufacturers to have them for nothing. On the contrary, as they receive a benefit from them, and as the water company is in the market and doing business to make profit, I can't see why the manufacturers should not pay.

Mr. Allen Hazen.* Mr. President, it seems to me that the evil of stealing water from city pipes is a very serious one. I know about these matters only occasionally and incidentally, but the frequency with which I have come across cases where manufacturers were drawing large quantities of water from pipes put in for fire purposes only indicates to me that it is a pretty prevalent vice, and I think that something ought to be done to check it. Just the best way of getting at it, I don't know. Mr. French's suggestion rather appeals to me, and I should like to see all these reports accepted, and a committee from this Association, acting with committees from other associations, take the matter up and see what means can be devised for making sure that pipes for private fire purposes are not used for other purposes.

Just as illustration of what may happen, I was in a small city a few weeks ago with Mr. Connet, to see what we could find out as to where a very large quantity of water was going. A Venturi meter was put on the supply, — Mr. Connet operated it, — the reservoir was cut out, and we pumped directly into the mains. The city was divided up into sections, each supplied through one gate, and those I had closed in rotation while Mr. Connet noted the record of the Venturi meter. In that way we found where the bulk of the water was going, and then followed it up. We found, for instance, that one mill which had a 6-inch pipe connected with the sprinkler system, and supposed to be connected with nothing else, — the mill was not paying a cent for water, — was drawing as much water as it was possible to get through a 6-inch pipe under a pretty fair head, something like four or five hundred thousand gallons per day. There were a few other mills which were n't drawing so much, but the water which was taken in that way formed a very considerable percentage of the total amount of water which was being supplied in the town. Now, I don't know what the best way to get at this may be, but

*Civil Engineer, New York, N. Y.

it certainly is a very serious evil, and an evil large enough to require very radical means for its treatment.

Mr. W. C. Hawley.* I notice the extreme delicacy of the gentlemen of the Committee about using the plain Anglo-Saxon word "steal" in connection with this matter. I can't understand it, unless it be on the principle upon which a case, which I heard of at one time, was decided, where a private company arrested an individual for stealing water, — that was the charge. The justice of the peace before whom the case was tried discharged the man on the ground that "water is free," and therefore could not be stolen. [Laughter.] I do not see why when that which represents capital, money value, is appropriated by one to whom it does not belong it is not stealing, and I think we make a mistake when we attempt to cover it over by using a smooth, easy word. Every waterworks official knows that water is stolen, and that many times it is stolen in large quantities. One of the largest water-works companies in this country was very nearly wrecked financially a few years ago by the deliberate stealing of water which went on for months. In spite of the vigilance of the superintendent of the company, and repeated efforts to locate the leak, which happened to be on a branch from the force main very near the pumping station, they were unable to find it until the company had been forced to make a large expenditure for an additional supply.

In regard to a method of furnishing a fire supply independent from the supply for manufacturing purposes, and doing it in such a way that the stealing of water can be detected, I found near Pittsburgh a very successful method in use, one which I believe is approved by the underwriters, and which is very satisfactory both to the manufacturing concern and to the water company. It was installed by my predecessor, Mr. W. A. Alexander, and was described by him at the Chicago meeting of the American Water Works Association last spring. A 12-inch main runs in, supplying water for manufacturing purposes. Parallel with that is another 12-inch main to supply the water for fire protection. A valve on this 12-inch fire line is operated by hydraulic pressure, — an hydraulic valve, — and is ordinarily closed. At one or more places through the plant there are connections from the ordinary service line to a pipe running to the cylinder on this hydraulic valve, and in case of a fire the turning of the cock opens that valve within a few seconds,

* Engineer and Superintendent Pennsylvania Water Co., Wilkinsburg, Pa.

and turns on the whole pressure for fire service. In order to detect the possible taking of water from this service, except for fire protection, a three-eighths inch meter has been connected to the fire line, discharging to a drain, so that whenever pressure is on this line the meter registers. The valve is tested at least once a week, and the tell-tale meter is read at the same time that the meter which is on the regular supply line is read, every day, so we can detect at once if any considerable quantity of water is taken from the fire line.

The President. If Mr. Kimball, of Knoxville, Tenn., is in the room, we should be glad to hear from him.

Mr. Frank C. Kimball.* The report of the Committee deals with practically two distinct subjects: One, the apportionment of charges for private fire protection, and the other the means of controlling the supply. Now, as regards the apportionment of charges for fire protection, there is, of course, a varied opinion, and the Committee seems to be divided on that more than they are on the other.

In a municipally controlled plant, it may be a question whether any charge should be made or not. That should be governed more, perhaps, by the way in which they keep their accounts, — whether they charge for hydrant service and fire protection, or, as was very pertinently stated yesterday, whether it all was charged up to the consumer. In a privately owned plant, such as I represent, there seems to be no question but what some charge should be made; there may be a question as to what that charge should be.

In our plant we have a charge, but that charge is graded or arranged in such a way that if our customer for fire protection is also a customer to a certain amount for water for other purposes, we give him his fire protection free of charge. That, I think, covers the case as raised by Mr. French. In other words, we are in business, of course, for what there is in it, but at the same time we are ready to protect our own customers. Those who are not our customers to any further extent than for fire protection we expect to pay for it.

Regarding the means for controlling the supply to manufacturers, mills, and other establishments, I think there is no difference at all, as near as I can find out, among the members of the Committee, that some means should be taken to control the supply. All men who have had any experience with water works, I think, will agree with me in saying that sooner or later, in some place or other, they have

* Superintendent of Water Works, Knoxville, Tenn.

run across cases of stealing, if you choose to use the word; although I am firmly convinced from my experience that a large number of the cases of the surreptitious use of water are without the consent or the connivance of the owners of the property themselves. In the South especially, more than in the North, pipes are laid underground more because there are few basements even to mills or manufacturing buildings, and it is the easiest thing in the world for an engineer who wants a supply of water at some part of his plant to shut a gate controlling the main supply, — they all have to be gated, of course, to conform to the underwriters' requirements, — make a tap dry, and run his supply pipe wherever he chooses underground; and I have yet to discover any adequate means of inspection which will take care of a pipe of that kind.

We have had some difficulty in our place on just this point, and two or three years ago we adopted a method of handling fire supplies, which was against their wish somewhat, I will admit, but has met the approval of the underwriters in that section, — possibly because they found they could not get a fire protection supply without it. [Laughter.] It is something that to my mind seems to overcome the objections that have heretofore been raised against metering fire protection supplies. We have no fire protection service larger than a 6-inch, and those we treat in this manner: A main line of 6-inch pipe is run into the premises, with a gate and indicator post on it as required, and around this gate is a by-pass of the same size as the pipe, 6-inch, on which, protected on one side by a valve and on the other by a check valve, a 6-inch meter is placed. (See Fig. 1.) This gives the full capacity of the pipe, and it also gives an opportunity to open this 6-inch gate in the main line, which ordinarily is kept closed and sealed, so as to give an additional supply, or give the supply that the meter may not give in case of fire; and at the same time the meter is of such a size that at the breaking out of a fire it will give practically all the water that is needed, and nearly as much as the main pipe itself will furnish. We then have the regular supply for the mill taken off inside of this gate and meter, so that the water used ordinarily passes through and is registered by this meter. That keeps the meter working, and it does away with the objection which is frequently raised that a meter on a fire line, not having any work to do, sticks and can't be used when it is wanted. It is inspected regularly once a month by the water company. Another thing which helps is that, according to the regulations of our company, a man in

our employ answers every alarm of fire, and it is his especial duty to look out for all gates on the line, such as this and others, and to see that the supply is all right. Until some arrangement is devised such as Mr. French mentions, as of a weighted check-valve or some other contrivance whereby the gate, which, for the protection of the company must ordinarily be kept closed, can be opened automatically, it seems to me as though this system which we have is about as good as anything.

In reply to a criticism which is made that a 6-inch meter will not register a small enough stream to account for all water that is used

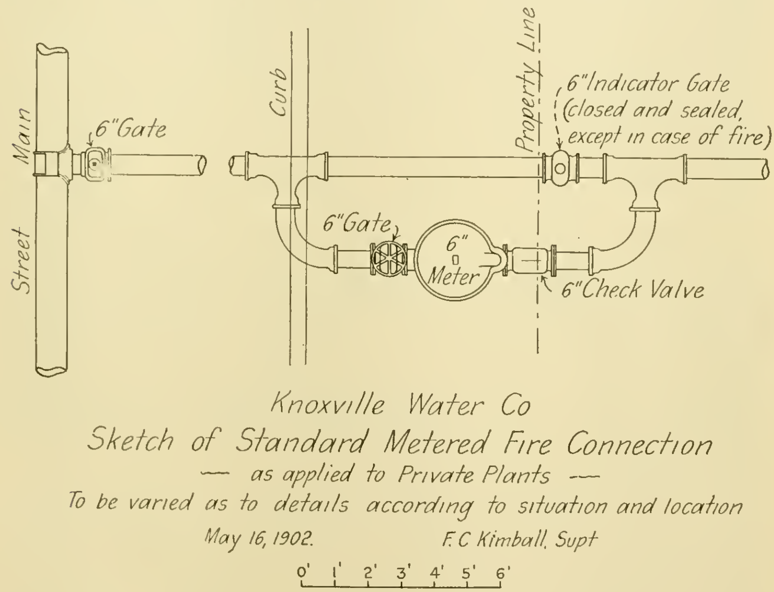

FIG. 1.

for ordinary purposes, I will state that the meters we use when tested before they have been placed have registered over ninety per cent. of an eighth of an inch stream, and over ninety-eight per cent. of a quarter of an inch stream, under thirty-five to forty pounds pressure, and if a manufacturer is using sufficient water to get fire protection free of charge the flow is sufficient so that there is practically, as meters go, no loss by lack of registration.

This plan that we have, I think, is at the present time the best that I have ever seen. It answers the purpose; it gives good protec-

tion; it is almost automatic, and it does away with just that thing that we are all troubled with, — the stealing or surreptitious use of water. That is one of the greatest evils, I think, that we have to contend with to-day.

I will say further, for it may be of interest to some members of the Association, that one manufacturer in our town rather objected to the arrangement, and was backed up by the underwriters who refused to accept the meter that we proposed to put on the pipe, although we were ready to demonstrate to him that under the system as we installed it we could furnish through that meter something over one thousand gallons of water a minute. He has taken the case into the courts, and I presume that if we live long enough we can get a judicial determination of whether that system is a proper one or not.

Mr. Kenneth Allen.* I should like to ask the speaker what the general type of meter is that he uses on that service, whether a rotary or disc.

Mr. Kimball. It is a positive registering meter. I would have no objection to giving the name of it, but I don't think it is exactly my business to advertise it. It is a positive acting rotary meter. And I will say further that the tests we have made of it show it is capable of delivering considerably more water than the manufacturer's limitation of it.

The President. Mr. Hammond, who started the ball rolling on this subject and has taken a great deal of interest in it, I am sure can say something to us at this time which will be of benefit to us, and I will ask him to address us.

Mr. J. C. Hammond, Jr.† Mr. President, I hoped to be able to keep still to-day, and I guess should have if you had let me alone. Mr. Crandall is our chairman, and I would most certainly like to hear from him, and then I may have something to say later. I am sorry our Committee could not agree entirely, although we did agree on one thing; that is, we all endorsed the commandment, "Thou shalt not steal." Now, when a man comes to us and wants us to lay a main pipe through a street where he has some building lots to sell, what do we say to him? We say, "We can't lay that pipe until you guarantee us a fair return." A man has a pipe put into his house and then goes off to the seashore for two months, and during that time does n't use any of our water, but still he has to pay for

* Engineer and Superintendent of Water Works, Atlantic City, N. J.
† Treasurer Water Co., Rockville, Conn.

it just the same. Some of us are staying at this hotel at four dollars a day, and suppose we happened to be invited out by some meter man to dinner, and we did n't want to pay for our dinner here because we had had it somewhere else. The hotel people would say to us, "Why, we had dinner ready for you here, and if you did n't eat it, it was n't our fault; you must settle just the same." Now, that is all there is about it. We have put our money into water works and we have water for sale, and a man can use it if he wants to. The manufacturer has this advantage, that if he uses a large quantity of water he gets a lower rate for it than a man who only uses a little. We put in a pipe for him for fire protection, which enables him to make a large saving in his insurance, and then he does n't want to pay us anything. They say that water is free and that air is free, but that is n't always so. You go down into the basement of this hotel and you will see some blowers, which make the air here very nice for us to breathe, and we say that air is free. But who furnishes the power and pays for running those blowers? [Laughter and applause.]

Mr. Kimball. If I may be permitted to say another word or two, in our town we have a condition of things which perhaps does not prevail everywhere. Our water is filtered, and there is absolutely no sediment in it as it is delivered to the consumer; consequently the danger of a meter clogging and thus being out of use at just the time when it is wanted does not exist, as it might in some other places where the water as delivered in its natural state contains more or less sediment and, as some of us have known, eels at times. Now it seems to me that the suggestion which was made to refer this whole question to a committee of the Association to act, if it can be done, in conjunction with a committee of the American Association and of the boards of underwriters, to formulate, perhaps not one but two or three or four plans or sets of suggestions whereby this matter may be handled without friction between the water companies and the insurance companies, is an excellent one.

The American Association at its meeting last June, after a report by a committee, passed a series of votes which, if followed out, would compel the placing of meters on all fire protection lines. While I firmly believe that that is a solution of the problem, still there are objections, as I know from personal experience, on the part of the underwriters against such a plan. I think, however, that a plan can be evolved, if all parties will go at the matter in the right

manner and in the proper spirit, which will be acceptable to all and will really be of advantage to the manufacturer. I have yet to find a manufacturer who is not willing to conform to the water company's rules if they are backed up by the underwriters' rules, or to the underwriters' rules if they are backed up by the water company. But as it is now he is between two fires, and he is going to protect himself if he can. If the various interests — the water companies, the public water departments, and the underwriters — can get together and formulate rules under which they will work in harmony and unison, I think this whole question will be settled, but I don't believe it will be settled until they do.

The President. We should be glad to hear from Mr. Crandall.

Mr. Crandall. I do not know, Mr. President, that I can add anything to what has been said on this subject. As far as I am personally concerned, my difference with the underwriters and with the insurance people is solely confined to the two points that were mentioned. I believe that the class of people who are wealthy enough to have private fire protection are not for that reason, simply because they are wealthy, entitled to get this better protection at the same price that a poorer protection is afforded to the average taxpayer. I also believe, and my experience has been such as to make it very apparent to me, that injury to others is liable to result from the presence of unnecessarily large services for fire protection, or too large services for any purpose. I do not want any larger service put into my house than is necessary to supply my needs, for an accident to it might cost me money. And when it comes to putting in such services as are now demanded for private fire protection and for elevators and for some other purposes, there is, I think any one but an insurance man would admit, danger to other interests — and I do not mean any disrespect to the insurance men. [Laughter.]

It may, perhaps, be interesting to members of the Association to know that in Burlington for a number of years past the fire protection of the entire city has been dependent upon the automatic action of a device for passing water around our high-service motor, about which you have all heard. This device acts from once a month to forty times a day, as the requirements may demand, and we have yet to experience any trouble on account of its failure to operate. Before the present device was in use, before our needs became such as they now are for large quantities of water in a short space of time, we had a similar arrangement of a check valve instead of a

butterfly valve, as we now use. That arrangement has been in use for twenty-two years, and the supply was never impaired on account of the failure of this automatic opening.

Reference has been made to the report of a committee of the American Water Works Association at the last meeting of that association, and perhaps it would be of interest to you to hear the report of that committee. I have the report here, and, if the President wishes, will read it.

THE PRESIDENT. I think it would be interesting to the members present to hear that report.

MR. CRANDALL (reading).

[*Report of Committee on Regulation and Control of Private Fire Service.*]

AUDITORIUM HOTEL, CHICAGO, June 13, 1902.

TO THE OFFICERS AND MEMBERS OF THE AMERICAN WATER WORKS ASSOCIATION:

Gentlemen, — Your Special Committee appointed to consider and report upon the question of the control and regulation of private fire service beg leave to report and recommend: —

That it be the sense of this Association, that the following regulations should be enforced: —

First. That all applications for attachments to street mains, for private fire service, be accompanied by a draft or plan of the proposed pipe system intended to be used on the property to be protected, together with a concise statement as to what other purpose the system might be used for.

Second. That upon approval of the application by the proper authority, its construction shall be such as to insure an accounting of all water used. Meters for this purpose to be installed and used.

Third. That by reason of the additional protection received by the property owner and because of the risk entailed upon other portions of the supply lines in case of a fire, it is eminently fair and just that there be made an equitable charge for every private fire service.

Fourth. That the objection of fire insurance companies to the use of water meters on private fire service attachments is not well founded, and should be opposed by the managers of water-works systems.

Fifth. That all expenses incidental to the installation of private fire service attachments, including cost of meters, be borne by the applicant or owner of the property.

Sixth. That the size of the openings for attachments shall be such as the engineer or superintendent shall find adequate, keeping in view, when deciding the question, the requirements necessary to properly protect other property on the same supply lines.

That to avoid surreptitious use of the water, devices be adopted by the superintendent and engineer to detect same, and in this connection we call attention to that of Mr. Alexander, of Wilkinsburg, Pa., as an example, and of which we will present a plan to the Association.

GEO. H. FELIX, *Chairman*,
C. E. BOLLING,
C. H. CAMPBELL,
Committee.

The device of Mr. Alexander is the one which Mr. Hawley described a little while ago.

Mr. Charles K. Walker.* Could I have a chance to say one word?

The President. I was going to say that this discussion would not be complete unless we heard from Mr. Walker. [Applause.]

Mr. Walker. When gentlemen speak about another committee, I want them to understand that your present Committee has done the very best it could. I don't think anybody could possibly have done more than Mr. Crandall has done, and I am sorry he had to do so much and that I could n't have done more, but I am an old man, and I did n't want to get into this any more than I could help. Now, I don't ever want to be put on another committee with these insurance fellows, for if there is anything in the world they can do it is to make long statements. Why, they can typewrite the whole Bible [laughter], and they will want you to read it; but they don't say anything about who shall pay for the supply which goes into one of their mills. [Laughter.] They leave that out entirely. They say they don't want to pay for it, and they make great objections to meters. I put in a meter one day and I thought I had it fixed all right, and then they came along and said the gate must be opened and the meter taken out, and finally I had to fix it so the mill man could get his insurance, and in the meantime the fire pipe was tapped; but I don't suppose the insurance people cared much about that.

I don't see that there is anything unfair about this proposition that Mr. Crandall, Mr. Hammond, and myself have made, that the manufacturers should pay for the privilege of having the water furnished to their buildings, because we have to keep the reservoirs in repair, and we have to keep the pumps in repair, and we have to do everything in order that they may have their pipes supplied with water. We certainly ought to have some compensation for it. I don't say it should be very much, but there ought to be some. You can tell a man he will have to pay $40 or $50 or $100, whatever you think he ought to pay. I should say he ought to pay more for a 6-inch pipe than he would for a 4-inch; and I am satisfied that a 2-inch pipe in most cases will do. If you have 80 pounds pressure and a 2-inch pipe through the mill, it will wet down considerably; I know it would in my house anyway. They refuse to pay one single cent, but I think

*Superintendent of Water Works, Manchester, N. H.

it is no more than fair that they or the insurance folks or somebody should pay for it. Mr. Cook used to be a water-works man, and in those days he stuck to the ship. [Laughter.] Now he has become an insurance man, and I don't take any stock in what he says. [Laughter.] He can get up and address this meeting a good deal better than I can, but I don't take any stock in him now, because he is an insurance man. He gets more pay, — all these insurance folks get more pay than we water-works men, — and so I don't blame Cook. [Laughter.] All I have to say is that I think it is fair that we should have some compensation for the water we furnish to the mills.

The President. Notwithstanding what Mr. Walker has said with regard to insurance men, I am very sure we shall all be glad to hear from Mr. Cook.

Mr. Byron I. Cook.* Mr. President, I am very sorry that I have lost the support of so able a man as my friend from Manchester, for I hoped he would still stand by me as he has many times in the past. But I think the olive branch of peace has been brought up from the South, and Mr. Kimball's idea is a good one. It seems to me that we are really very near together. What is wanted is a device of some sort to be placed on the fire supply that will be accepted by both parties. There is no doubt that some such thing is needed.

Now, so far as the matter of charging for fire protection is concerned, it seems to me that every city and town has a duty to protect its manufacturing industries. The factories in a town are what support the town and give it its income, and when competition is as brisk as it is to-day no town can afford to lose its factories by fire and run the risk of their rebuilding elsewhere. I think the suggestion that a committee be appointed from this Association to confer with committees from the National Board of Underwriters and from the American Water Works Association, with a view to devising some plan by which the water interests and the insurance interests can be protected, is a good one.

Mr. R. C. P. Coggeshall.† There is one thing I have noticed about these fire supplies. Even assuming that the fire service uses no water, yet if a superintendent will take the trouble to put a meter on the by-pass around the main gate in one of these large factories,

* Inspector Associated Factory Mutual Insurance Co.'s, Boston, Mass.
† Superintendent of Water Works, New Bedford, Mass.

when they are not drawing a drop of water, he will be surprised to see how much water is going away in leakage underground in almost every case. I venture to say he will find from six gallons a minute upwards going, and it is almost impossible to trace it because it is going in such minute quantities. Now, should n't there be something paid for that amount of water, which is going all the time?

THE PRESIDENT. We should be glad to hear from Mr. Fiske, who is a member of this Committee.

MR. HENRY A. FISKE.* Mr. President, I do not feel like saying very much on this question. I was the last member appointed on the Committee, one of the younger men, and I simply tried to do my part in the committee work. Perhaps I have spoken a little freely in the Committee, but if I have it was because I felt strongly.

The one thing I am most sorry for is that the Committee could not have brought in some sort of a unanimous report, not so much on account of the good that that report might have done, but because it might have avoided giving the impression to some people that there is any antagonism between the water-works interests and the insurance interests. As matter of fact there is none and should be none. There is no reason for any antagonism, not the slightest; and the only reason that there was any difference of opinion in the Committee was because the members took different views as to the equity of the case on just one point. On the main features of the case under consideration, and those which I think will be by far the most important in the future, we were entirely agreed. One great feature, it seems to me, of the work — and when I took it up I, perhaps wrongly, imagined that that was about the only feature this Committee was to take up — was that relating to properly guarding against the misuse of water. I knew that Mr. French had worked on the subject of the by-pass and other devices, our National Fire Protection Association had discussed similar devices, having had this thing up for a good many years, as to what to do to make sure that water was used for fire protection purposes only. The insurance people are with the water-works people heart and soul on that. There is no difference of opinion about it. We do not want the water used for anything but fire purposes. We believe it is an absolute detriment to the service to use the water for anything except the extinguishment of fire, and we impress that upon the assured: and if we find the assured using the water for any other

*Secretary, Underwriters Bureau, Boston.

purposes, we use our best endeavors to get him to stop doing it, and generally give him a positive command that it must not be done. And I know that it is a fact that the insurance interests throughout the country are working along in that same direction.

So, when you come right down to it, really the one subject which it seems to me this Committee had before it, or which any similar committee will have, is the question of devices for determining whether water is used for other than fire purposes. That is a very important question and one which will, I think, demand a great deal of work; and I am sure that the insurance people are ready to put their time and energies into this, in connection with the water-works people, in order to come to some conclusion which will be of advantage to all concerned.

Mr. French. Mr. President, if I may be allowed one word, I would like to heartily endorse all that Mr. Fiske has said. In business we are competitors, but when it comes to the matter of fire protection our interests are identical, because protection is something which is equally desirable irrespective of where the insurance is, whether the property is a "stock" risk or a "mutual" risk. One or two points have occurred to me as possibly helpful to this discussion, and I will try to state them briefly.

First, once for all, let me explain where we differ in *principle*. Mr. Crandall's position is that protected mills get considerable advantage in insurance rates, — and they certainly do, — and that they ought to pay something to the public for this advantage. But our feeling is this: A man pays taxes; you all pay taxes. Now, if your house takes fire the public department comes and uses the public water freely, without any charge to you, and puts the fire out if it can. You have that service because you pay taxes. The proprietor of a large dry goods store down town, whose store has no private protection whatever, is entitled to the same service, and it is not an uncommon occurrence for the public fire department to pour water on such a store all night, perhaps until there is nothing but the cellar left, and no one questions the owner's right to this service. Now, we have felt that a mill owner has a right to say to himself: "If I put in automatic sprinklers, the chance of a fire getting under way is much lessened, and consequently the chance of my plant being destroyed is greatly reduced. I am entitled to fire protection because I pay taxes, and all I ask is that I be allowed to have that protection through the sprinklers which I will buy with my own money." These

sprinklers are better tools for using the public water than the public can furnish to the community at large. The only way to get these better tools is for the individual to purchase them; and the owner of the protected risk merely asks that the water that is standing in the mains in the street, ready to be played on to his property if it takes fire, be allowed to stand on his sprinklers, because he believes that the water will do more good, it will be more effective on his sprinklers. Really, it seems to us that the man is helping the community to bear the general responsibility of extinguishing fires and lessening the chance of a great fire. Now, because we felt that having paid taxes he had paid for that protection once, we thought it was not fair to make him pay for it again; and although what Mr. Crandall wants to charge is possibly no more than the man will have to pay to reimburse the water department for reading the detecting device, when we finally have a perfect one, nevertheless we felt that there was a fundamental principle, a question of right, which ought not to be covered up by a compromise, and that is why we took the position which we did.

I want very much to emphasize what Mr. Fiske says, that there should not be any antagonism between the insurance interests and the water-works interests, and we want to work harmoniously and strive for the same end. We are absolutely opposed to the stealing of water, and it ought to be stopped in every place where it is discovered. We feel that perhaps, after we have settled the principle of the thing in our minds, the chief work for us will be to find some sort of a detective meter, to devise some arrangement which cannot be objectionable to anybody, something that will not in any way decrease the efficiency of fire protection, and something that will give absolute security against all improper uses of water through the fire service. We have put a good deal of time into the consideration of that matter and made a good many experiments, and we think that something will eventually be developed.

Now, one other point is this: Mr. Walker has raised the question of the amount of water needed, and I just want to say that all our experience goes to show that now and then there comes a fire which will open fifty or one hundred automatic sprinklers. That happens sometimes owing to the fact that the fire burns in a place which the water cannot reach. For instance, in the mule room of a cotton mill it is not uncommon to have a fire in the mule-carriage. We had one the other day which opened two hundred sprinklers; if the water

supply had been better it would not have done it. But the fire sometimes burns in such concealed places, necessarily concealed in this case, because you cannot put sprinklers in a moving carriage; and the heat spreads through the room until the number of sprinklers which open is sufficient to pour out water fast enough to cool that heat as fast as it is made, and then no more sprinklers open. Now, if you limit your water supply to a very small pipe, the heat may go the whole length of the room and open every sprinkler, and when the large pipe is turned on, as Mr. Walker suggests, there will be a very heavy water damage; while if you have ample water to supply all the sprinklers which open at the very start, that water will catch the fire in its infancy and hold it, and you can perhaps shut the water off in a few minutes with a comparatively small loss. You take away from the great good of your sprinkler equipment the instant you throttle your water supply, for often you don't want many gallons in the total, but you may want a good many gallons in the first five minutes. That is a very important feature in fire protection.

Just one word more. As to this arrangement of Mr. Alexander's, I am afraid it would not be wholly safe in its present shape, because our experience with automatic dry pipe valves and various other automatic devices is that they are very likely sometimes to fail; and further with automatic sprinklers, if you had to wait until somebody pressed the button and opened the hydraulic valve, you would probably hamper your sprinklers at the start, when they need water the most. But somewhere among these various devices there will be something found which will give us a chance to stop all the improper use of water, which is very rightly named stealing, and when we get to that point I think that this question will very largely disappear, and that all water departments will be very glad to do all they can towards putting out fires, providing they can be sure that their fire services will not be abused.

The President. I will ask Mr. Chase if he desires to say anything upon the report which he has made.

Mr. Chase. Well, Mr. President, practically everything which has been said to-day has been a rehash of what we have heard at previous meetings, comparatively few new ideas having been advanced; and while I might assume that there is justice in my cause, yet I believe justice should be tempered with mercy, especially about dinner time, and as it is now half-past twelve, I do not think I will inflict any remarks upon you.

On motion of Mr. R. J. Thomas, the convention adjourned to 2 P.M.

Upon reassembling, Mr. Fred Brooks moved that the three reports presented by members of the Committee on Apportionment of Charges for Private Fire Protection and the Means of Controlling the Supply Thereto be received and printed. The motion was adopted.

MR. CRANDALL. I was not here when the convention was called to order this afternoon, and I do not know what action was taken in regard to the reports of the Committee on Private Fire Protection. I would like to know what action, if any, was taken on that matter.

THE PRESIDENT. The reports of the Committee were received and ordered to be printed. That was the motion which was made and passed by the Association.

MR. CRANDALL. If there has been no motion made to carry out the suggestion in regard to appointing a committee to confer with committees from other associations who may be sufficiently interested in the matter to appoint such committees to consider the question of the control of such private fire services — I understand there has been no such motion made?

THE PRESIDENT. No such motion has yet been made.

MR. CRANDALL. Then I would move that the Chair appoint a committee of three water-works men, members of the New England Water Works Association, residing within fifty miles of each other and within one hundred miles of Boston, to take up this matter with committees which may be appointed with other associations.

Adopted.

MR. CRANDALL. Has there been no expression of opinion by the Association with regard to the different reports which were presented? There was a motion made this morning in regard to the adoption of one of the reports; was that acted upon?

THE PRESIDENT. All the business which was done, Mr. Crandall, was the passage of the motion to receive and print the report.

MR. CRANDALL. As a member of the Committee, I do not feel like making any motion in that regard, but it seems to me that an expression from the Association at this time would be very opportune.

MR. PAULISON. I move that Mr. Crandall's report be accepted and adopted.

A MEMBER. It seems to me that as we are about to appoint a

committee to confer with committees from other associations with regard to this matter, it might be somewhat premature for us at present to endorse any one of these reports. Perhaps it would be better to let the matter lie, to give the members an opportunity to think the matter over when they can have the reports in print, and at some future meeting they can endorse whichever report they choose.

Mr. Kimball. While personally I am wholly in accord with the report presented by Mr. Crandall and his associates, I think myself that the better way to handle this matter now is to accept and print all of the reports, — there are some good things in all of them, there is no question about that, — and then give this new committee all the papers in the case, and let them, after consultation with committees of the American Water Works Association, of the Underwriters and other associations, if it is deemed best, bring in a report of what they think is advisable in the case.

I am sorry that Mr. Crandall in making his motion limited the choice of the President to certain districts, because that cuts out, perhaps, some members of former committees who have discussed this matter pretty thoroughly and are perhaps as competent as any one. If it is in order, I would move to amend the motion so that all limitations may be taken off the appointment of the committee, except, I believe, it should be composed of representative water-works men, and men, if you please, who represent both municipally and privately owned plants, as the underwriters, the insurance men, would naturally appoint a committee of their own to confer with our committee. If it is in order, or if it can be got at in any way, I think the limitation as to the location of the members of this committee should be removed. Will Mr. Crandall accept that as an amendment, if it is not too late?

Mr. Crandall. I am willing to accept the amendment, providing you leave out the present superintendent of the water-works at Burlington, Vt. But the point I wish to get the sentiment of the Association on, and that I thought it would be advisable to have an expression of the Association upon, is that with regard to which the American Association has expressed its opinion, that is, as to whether this Association believes in free water for private fire purposes, or whether they believe that private fire services are assessable; and, also, on the other point as to whether there should be a limit placed upon the size of the services attached to the public

mains, — not necessarily a limit to the size of private fire pipes, but a limit to the size of any kind of services through which water may be drawn from the supply suddenly. The new committee appointed will be as much at sea with regard to what the opinion of the Association is on these two matters as we were. There is no question what the opinion of the insurance men will be, or of a man who is in charge of a large manufacturing plant, and if there is any considerable sentiment among water-works men in the same line as that which exists with the insurance men and the owners of the protected risks, I think it would save the committee a good deal of work to know it beforehand.

Mr. C. W. Sherman. I do not pretend to be very much of an expert in parliamentary law, but it seems to me that the original motion having been adopted by vote of the Association, the only way to make the change suggested by Mr. Kimball will be by a reconsideration of the vote and taking the matter up entirely anew.

Mr. Crandall. I am willing there should be a reconsideration on the terms I have mentioned.

Mr. George F. Chace. This present assembly is a very small part of the New England Water Works Association, and it does not appear to me that we can vote very intelligently upon matters about which we have never heard and know nothing. For my own part I do not know what the details of these reports are, and I should be glad to see the reports printed. It seems to me we could express ourselves a great deal more intelligently if we knew the details and had time to adjust them. I move that the whole matter be laid upon the table.

Mr. Paulison. I think if Mr. Crandall's report were adopted it would be a great help to the future committee to know the wishes of the Association.

Mr. M. N. Baker. I would like to make this statement: It seems to me that, inasmuch as the attendance now is so very much smaller than it was this morning during the discussion, or in the early part of the afternoon when the other motion was put and adopted, and inasmuch as some of the members who are interested in the discussion have, I believe, left the city with the understanding that final action had been taken, there might be an element of unfairness in re-opening the subject until notice has been given that it is to be taken up again. I say this without any regard to the manner in which my sympathies run on this general subject.

Mr. Crandall. Mr. President, I appreciate the fairness of what Mr. Baker has said, but I would still like to know what the sentiment of the people here present is, not as a statement of the opinion of this Association, but simply for the information of the Committee as to what the opinion of the people now present is on the subject.

Mr. Chace. Does n't the motion to lay on the table take precedence?

The President. I believe it does.

Mr. Fred Brooks. It seems to me if the motion to lay on the table prevailed it would still be open to the gentlemen present, if they chose, to make some informal expression, which would not go on record at all, as to how many favor and how many do not, the point suggested.

The motion to lay on the table is carried.

Mr. Kimball. Now, with Mr. Crandall's permission, so that we can strike out the limitation, I move to reconsider the vote adopting his motion, with a view to offering it in another form covering practically the same matter.

Adopted.

Mr. Kimball. Now, I would move that a committee of three be appointed by the President, whose duty it shall be to ask for the appointment of and to confer with similar committees from the American Water Works and other kindred associations, and also with the various underwriters' associations, to agree, if possible, upon some adequate means of controlling private fire supplies acceptable to all parties concerned, including therein all questions relating to charges therefor and similar matters.

Mr. Hammond. I understand the question of payment is eliminated now, that it is simply to devise some means of detecting the use of water and has nothing to do with the pay; am I right?

Mr. Kimball. I think the question of control includes payment as well as other questions connected with it. The question of payment is one form of controlling in all these things.

Mr. John O. Hall. I was not present this morning at the discussion of this subject, but I trust that the committee will have ample authority to cover the whole ground, because I believe it is a vitally essential point in the matter of water-works operation and control. A remark was made yesterday in reference to a just return to the water department for all demands made upon it, and it seems to me

that here is a question that the communities are vitally interested in. The community should not be taxed, the individual taxpayers should not be compelled to bear any burden which by any interpretation can pass into an individual benefit to somebody else; and this whole matter, it seems to me, should be very carefully considered, and the committee appointed should have ample power to cover the whole ground and take in the whole bearing. This is an element of vital importance to water-works departments, which are servants of the communities, and they should be very careful to protect the communities which they serve.

Mr. Sherman. I rise to a point of order, Mr. President. If I understand parliamentary law correctly, the motion to reconsider the vote on Mr. Crandall's motion having been carried, the question now comes on Mr. Crandall's original motion.

The President. Do I understand that Mr. Crandall accepts the motion of Mr. Kimball as a substitute for the original motion?

Mr. Crandall. Yes; with the understanding that the President in his appointment will except the superintendent of the Burlington works.

Mr. Kimball's motion was adopted unanimously, and the President announced that he would appoint the committee later.*

Mr. R. J. Thomas. Inasmuch as the committee's report is not adopted, would n't it be well to discharge the committee now that you are to appoint another one?

Mr. Hammond. I think the committee should be discharged, and thoroughly discharged.

Mr. Thomas. I move that the committee be honorably discharged.

Mr. Kimball. With the thanks of the Association for the work which they have unquestionably put into this matter.

Mr. Thomas. I do not accept the amendment, for I do not believe in thanking committees. I move that they be honorably discharged.

Adopted.

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*Subsequently the President appointed Messrs. F. H. Crandall, R. J. Thomas, and Elbert Wheeler as members of this committee.

APPENDIX A.

Statement of Conditions and Conclusions submitted by Messrs. Crandall, Walker, and Hammond, to the Fire Pipe Committee.

Investigations and experiments made for our Committee develop the following conditions: —

Water-works systems, both public and private, as we have them, are generally constructed with at least a double purpose in view, — the furnishing of fire protection and of water supply, both of which, under some circumstances, may be regarded as public necessities. In most cases it is not until a combined necessity becomes apparent that water works are built. Whether the necessity rests principally on account of the fire protection or the water supply afforded by the works, it matters not, as the need of either is sufficient to warrant the claim.

It is often forcibly impressed upon those in immediate charge of a system that much necessary work might more easily be accomplished and large expenditures frequently avoided were it not for the temporary impairment of some one's fire protection.

In case of public ownership of the water plant, the practice of making, in one way or another, a contribution toward the expenses of the water department in recognition of public fire protection afforded, and that of furnishing private fire protection and permitting fire services to be used for other than fire purposes without the knowledge or permission of the department, and without remuneration, is quite common.

Public sentiment, or the sentiment of the law-making representatives of the people, is found frequently averse to the strict enforcement of ordinances generally enacted for the prevention of the misappropriation of water.

Under public ownership, private fire protection has been frequently furnished without charge, the understanding being that such services should not be used for other than fire purposes, that the cost to the water department would be inconsiderable, and that the value of the protection afforded was not so great as by its free concession to constitute an injustice to other taxpayers.

Furnishing fire protection in accordance with present ideas necessitates larger mains than formerly, and much larger mains than, but for rendering private fire systems efficient, would prove amply sufficient. In recent years a large part of the annual expenditure of many works has been solely on account of fire protection. Pipes are everywhere being replaced with larger sizes for no other reason than to maintain the efficiency of plants for private fire protection.

Wherever pipes supposed to be used for fire purposes only are in use, water in considerable quantity is taken from them occasionally, if not habitually, for other uses.

The general public have had no opportunity to become aware of the extent to which the confidence reposed in the users of private fire services has been misplaced, nor have they had occasion to become possessed of correct information as to the value of the service rendered in permitting the connection of private fire protective plants with the public mains.

Every year's additional experience is making more apparent the shortcomings of the schedule rate and the so-called free systems, both in that

they offer no incentive to individual economy and thrift, and in that they indirectly encourage wastefulness and a disregard of the rights of others.

With the increasing popularity of the meter system, and its accompanying idea that one should pay for water in proportion to its use, the idea that the expense of fire protection should also be borne by those benefited in proportion to benefit received has gained in popularity.

With the increase in the number of small takers, ordinarily paying the minimum meter rate, and occasionally paying a larger bill on account of waste, a strong sentiment in favor of requiring every taker to assume the responsibility of meeting the expense of his own waste is developing.

The inadequacy of any means, short of placing the cost of waste upon the parties permitting it, to prevent the useless and unnecessary waste of water, has been repeatedly demonstrated.

It has developed that, under either the schedule rate or the so-called free system, no reasonably adequate supply can long prove sufficient.

The amount of water legitimately used or wasted by private fire pipe systems is not inconsiderable. The cost to the water department of maintaining the efficiency of private fire systems is not a small item. The pecuniary benefit accruing to the possessors of such systems in saving of insurance premiums is real, tangible, and considerable.

There is no question as to the value of and benefit to be derived from properly installed systems for private fire protection; nor is there any question as to who is the directly benefited party. The general public, like the beggar at the rich man's table, gets some crumbs of benefit from private fire protection, but there the parallel ends. The public is asked to foot the entire bill. Though the town derives benefit from the presence and from the sprinkling of its manufacturing industries, they are neither built nor rebuilt nor sprinkled for the benefit of the town.

Reasonably trustworthy evidence in regard to the method of use of private fire pipes is to be had at small expense.

The matter of expense necessary to be incurred in securing reasonably trustworthy evidence in regard to the method of use of private fire pipes is of no consequence whatever, as, be the expense what it may, it will, in a very short time, be returned manyfold in the prevention of waste, if in no other way.

Losses of ten pounds or more in pressure are not infrequently traced to leaks from private fire services, which have, perhaps, been running for months, but which, inasmuch as they did not cost the mill people anything, they did not feel were of sufficient consequence to merit attention.

In furnishing fire protection in the manner which has become quite generally the custom, even with the utmost care and the best installation, a risk, not only of absorption to no purpose of pressure, perhaps sorely needed on the premises or elsewhere, but also risk of unremunerative use and waste is assumed. The risk of loss of pressure here referred to is that of the entire absorption to no purpose of the fire protective efficiency of a plant, as by the discharge from a line broken by falling walls or from sprinkler heads in an already doomed building or in a building where the fire has been extinguished.

Such utter destruction of the fire protective efficiency of the water plant was experienced at Manchester, N. H.; Jacksonville, Fla.; Columbus, Ind., and other places, on account of the presence of unreasonably large services.

Very few of our systems can suffer the breaking of a 6-inch service and yet furnish fire protection to the neighborhood, hence the unwisdom, if services of that size are to be permitted at all, of permitting them to be so located as by any possibility to become broken.

The gate, supposed to be so located as to be accessible under any probable combination of circumstances, is about as apt to get shut when it should be shut as the gate on a by-pass around a meter is to get opened when it should be opened.

An investment in private fire protective appliances, supplemented by many times the amount invested in a water-works system, secures a saving in insurance premiums due to the entire amount contributing to the protection of the plant, and ordinarily affords the owner a large return on the comparatively small amount invested in private appliances.

The owners of private fire protected plants would have it understood that a water company or department is not entitled to remuneration for private fire protection, but only for the cost of connecting to such fire protective systems and the cost of reasonable supervision of the use of water from them.

Complex systems of cast- and wrought-iron pipe under from forty to one hundred and twenty pounds pressure can be maintained with scarcely any leakage. Such services are, nevertheless, where the conditions are such that waste costs the taker nothing and repairs are expensive, frequently found wasting considerable quantities of water.

These conditions have been demonstrated with particular clearness and force where the use of water for some time, without the knowledge of the user, measured, has been transferred from the schedule or so-called free list to the metered class. Premises where the users of water pay for use and waste at meter rates in proportion to the amount supplied are being satisfactorily served with one fourth the amount which was consumed when the water department, and not the careless and extravagant consumers, suffered the loss incident to waste.

Nowhere have these conditions been more conspicuously demonstated than in instances of public use. The caretakers of public premises where constant leakage from closets and other fixtures, and from fountains during the night time and during rain storms, has been the custom, have, when the loss incident to permitting such conditions was placed upon them, found that just as satisfactory results could be achieved with from one fourth to one third the amount of water used under the plan in vogue when the loss due to waste did not come out of their appropriation, and the benefit resulting from the better example has been worth more than the saving in water.

Statistics of like and even more advantageous results, achieved by causing the waste from private fire pipes to fall upon those permitting it, are not wanting.

The mill mechanic is not, and is not generally considered, the responsible cause of certain peculiar practices in regard to the use of private fire pipes, which have in numerous places come to light.

The agent, owner, or managing stockholder, who smiles when his engineer explains to him the ease with which the fire service may be tapped, and the party who, under the mistaken impression that he thereby furthers his own pecuniary interest, fosters the impression that a charge for private fire protection is unjust, and suggests means for "getting even" with the water company, are, beside public opinion, the forces to be reckoned with in an attempt to improve present conditions.

We find no means of securing reasonably trustworthy information in regard to the use of services used for both fire and other purposes. In regard to the use of such services, it appears that the manufacturer who told one of your Committee that, in spite of the best efforts of the water department, he could obtain, without their knowledge, all the water he wished from his fire service, was possessed of information on the subject no less accurate than that born of experience.

It is not on account of the illegitimate use which is likely, sooner or later, to be made of private fire pipes that meters are used, and a charge is, in many places, made for private fire protection, but for the prevention of waste, and because the protection thus afforded is of value and not reasonably to be granted for nothing.

The city of Burlington, Vt., has for years been dependent for fire protection upon the automatic opening of a by-pass around the motor used to

supply the high service, and has yet to experience any difficulty on that account.

Metered by-passes around weighted check valves are, in different places, affording means of securing, at small expense, reasonably accurate information as to the amount of water used through certain classes of services.

Metered by-passes of a much smaller size than the fire services, around gates in which they are placed, are, in some places, systematically used to determine the amount of leakage from services so equipped. Either the proportional device upon which the Factory Mutual people are at work, or a device such as is in use at Wilkinsburg, Pa., will furnish accurate information as to whether a service is used or not. As to the amount of water taken from a service, neither is constructed to furnish accurate information. For use on street sprinkling standpipes, or elsewhere, where the stream drawn is always the full capacity, either device affords reasonably accurate information as to the amount of water passing through it.

So far as we are able to learn, the device in use in Wilkinsburg, Pa., and some other places, for securing information in regard to the use of private fire pipes, is efficient, and not liable to get out of order. It consists of a hydraulic valve, with a small drip opening the instant the valve leaves its seat. By means of a meter on a waste pipe from the drip, the length of time which the valve remains off its seat is ascertained. The valve may be opened by means of stops on small pipe lines conveying hydraulic pressure to its operating chamber, from as many points as may be desired.

Superintendent W. S. Hamilton, of Youngstown, Ohio, has applied for a patent on a device consisting of a small metered by-pass around a large meter and check valve, which, it is stated, will be accepted by fire insurance companies.

We have been able to agree with the members of our Committee representing the owners of private fire protected plants and the insurance people on the following propositions: —

First. That the owners of private fire protected plants would have it understood, as was formerly quite generally the case, that by means of their private fire protective appliances, put in at great expense to them, they merely utilize to greater advantage protection to which they are legally entitled, and are not the recipients of any special service or protection.

Second. That stealing water from fire services is not right, and should be stopped.

Third. That the obtaining of trustworthy evidence in regard to the use of private fire protective systems is a growing tendency, and is entirely reasonable.

Fourth. That under schedule rate, or so-called free service, the appeal to the pocketbook is in favor of increased waste rather than economy, repairs being expensive, and a continuance of waste costing the taker nothing.

Fifth. That the work of this Committee will be of more value if mainly directed to securing a remedy for the misuse of private fire connections, rather than to the preparation of elaborate records of past abuses.

Sixth. That on every fire service running into a building there should be a main gate, so located as to be accessible under any probable combination of circumstances.

Seventh. That a charge for a permit to connect, equal to the cost to the public or to the water company, as the case may be, of the connection, would be reasonable and proper.

Eighth. That an additional charge for each additional hundred feet of water used in excess of the amount allowed for the minimum rate would be fair and reasonable.

Ninth. That in a constantly increasing number of cases, where to secure fire protection and water supply for a reasonable sum it has become necessary to limit the consumption to legitimate uses only, no so-called free use

and no waste being permitted, metering of private fire services is certainly a growing tendency. We, however, do not expect the custom to become universal for many years, if ever, and we think that probably, in a number of cases, metering will not be necessary, such methods as are employed in New Bedford and Providence perhaps, under some circumstances, sufficiently safeguarding the interests of the public.

Tenth. That existing conditions undoubtedly create a tendency to use meters of the ordinary commercial types for fire services. Our feeling is, that though present types of meters are not entirely satisfactory for the work, on the one hand through their inability to measure small flows, and on the other because of their possible excessive obstruction in case of large demands, they will, unless something more satisfactory is devised, probably be placed on private fire services.

Eleventh. That as a general proposition, taxpayers, required to pay for all they use and waste, may reasonably demand that others do the same and that trustworthy evidence, such as an automatic machine only can furnish, in regard to the use of a service, be secured in regard to the use of every service attached to the public mains. We, at the same time, appreciate that probably, in many cases, the interests of the public may by other means be duly safeguarded.

Existing conditions are, we find, in various ways demonstrating the impropriety of furnishing private fire protection for nothing. From the conditions as we find them, we would draw the following conclusions: —

The conditions encountered in different places are so different as to render impossible any conclusions of general applicability in regard to the amount or method of making a fair and equitable assessment for private fire protection.

The understanding that a service, supposed to be used for fire purposes only, furnished as has been the custom, will be used for no other purpose; that the cost of maintenance of such services for such purposes only is insignificant, and that the value of the protection afforded is not so great as by its free concession to constitute an injustice to others, is, in every particular, a misunderstanding.

The improper use of services, relative to the use of which no means of securing reliable information is furnished, is a natural consequence of their existence, to which the small value frequently placed upon private fire protection largely contributes.

It is not unnatural that the appropriation of a commodity esteemed to be nearly, if not quite, valueless, should be regarded as a trivial matter. Wherever the misapprehension, quite common at present, as to the value and cost of fire protection is coupled with an apparent willingness of water rate payers to bear the burdens of others, the present rates or lack of rates for private fire protection and the present method of use of such services may reasonably be expected to continue.

It is not wholly the well-known tendency to generosity with other people's money, but largely a lack of correct information as to the value of the service rendered, which is responsible for the discrimination frequently existing in favor of the ownership of private fire protected plants.

The granting for nothing of so valuable a service to parties abundantly able to pay a reasonable price for it is not charity, and amounts to more than ordinary generosity. It amounts to an injustice to other rate payers, which, in view of the fact that in the establishment of rates for the service of a public monopoly, neither charity nor generosity but justice only ought of right to figure, is conspicuously ill met.

Where the furnishing of private fire protection results in either expense to the furnisher or in benefit to the recipients of the protection, there should, in justice to all concerned, be a proportionate assessment.

With an increase in either the value to the applicant of the protection afforded, the cost to the water department of affording the protection, or

the risk to other interests entailed by the attachment desired, the rate for private fire protection should increase.

All known safeguards having been provided to lessen the risk to other interests, incident to the attachment of a large service to the system, the only way of meeting the unavoidably remaining risk is by its assumption by some one.

Though there are occasional instances of the assumption of a risk by one party for another without remuneration, the practice is not general, and we see no reason for its adoption by water departments.

By causing the rate charged for private fire protection to increase as the risk to other interests entailed by the service is increased, the creation of needless hazard incident to unnecessarily large services will be discouraged.

Large services, for whatever purpose, carry with them an element of danger to the neighborhood, and care should be taken not that fire pressure may not be accidentally destroyed, but that it must not be accidentally destroyed.

The misapprehension, which has become quite common in regard to the value of fire protection, results, it seems to us, largely from the practice of thinking and speaking of furnishing water for fire protection, instead of speaking and thinking of furnishing fire protection.

The extra cost of furnishing facilities for securing water in volume sufficient for fire protective efficiency is not conspicuously apparent to those not versed in such matters. To such a bill "for water furnished for fire protection," particularly if no water or very little water has been so used, is a stumbling-block.

Inasmuch as at current prices the cost of furnishing the water used for fire purposes forms so small a portion of the cost to the water department of furnishing the protection, a bill for "fire protection afforded," the form of expression in use in many places, is technically more correct, and perhaps affords less opportunity for misunderstanding.

That there should be misapprehension in some quarters in regard to the value of fire protection is not particularly strange. The minimum meter rate has often, at first, by some been regarded as an injustice. With better information on the subject, the legality and propriety of such a charge has come to be generally recognized, and meters for small consumers, expecting to pay the minimum rate, are in demand. With the increase of correct information on the subject of fire protection, a reasonable charge for fire protection, both public and private, will also be not only appreciated but demanded.

While differences of conditions to be met with in different places seem to render conclusions in regard to the amount and method of assessment for fire protection which shall be generally satisfactory out of the question, the relative value of services of different sizes is, under the various conditions encountered, approximately the same, and the charge for a 6-inch service may reasonably be made not less than from four to six times that of a 2-inch service under like conditions.

The water company or department placing at the disposal of a patron a plant the fire protective efficiency of which he could not duplicate for a hundred thousand dollars or more, and which it has, perhaps, cost several hundred thousand dollars to develop, is entitled to reasonable compensation for benefit in the form of fire protection, as well as in the form of water supply derived from attachment to the plant.

There is no doubt that in the past water companies have quite generally derived an unreasonably large proportion of their revenue from those to whom they have furnished water, to the great pecuniary advantage of those to whom they have furnished fire protection.

All that can be said in favor of the meter system in preference to the schedule rate system applies with equal or greater force in favor of secur-

ing reasonably trustworthy evidence in regard to the use of private fire pipes, in preference to furnishing such service without control or remuneration.

No municipal or private corporation can afford to imperil its plant and put its property where it can be used without its knowledge or consent, trusting to the user to make proper compensation.

A plumber could not be legally or reasonably compelled to permit A, B, C, and others to help themselves to his wares, trusting to them to make him a proper return. This very unusual method of doing business is no more legal or reasonable when applied to a water company, either public or private.

To the rule that everything may be carried to an extreme, the size of an automatic sprinkler supply is no exception. In this case we feel that the extreme is quickly reached. An automatic sprinkler may, by being at the right place at the right time, prevent a conflagration. Ordinarily the fire which opens more automatic sprinkler heads than a 4-inch service will supply has passed beyond the automatic sprinkler class, and brains are required for the direction of the deluge necessary to arrest its course. In any case, such a service should not be permitted without facilities for the prevention of its becoming a damage instead of a blessing.

The interest and other expenses of maintenance, a proper sinking fund contribution included, together make up the cost of supplying water and fire protection. To meet this expense, each party deriving benefit in any form from the maintenance of the plant should be assessed in proportion to the benefit he receives and his ability to pay.

Reasonably reduced rates to wholesale consumers of water are, provided for like quantities of water the rate is always the same, legal, and in such case do not create a material, if any, departure from assessment in proportion to benefit.

The claim that any sharer in the advantage, of whatever nature, conferred by a public water works should be exempt from making a proportionate contribution towards the general maintenance of the plant, interest included, is not well founded.

Referring to the four definite questions submitted to us, we find, —

In regard to the first, as stated a year ago, the opportunities for taking water, without the knowledge of the water department, afforded by the presence of private fire pipes, are frequently taken advantage of.

In regard to the second, the benefit to the general public from the presence of private fire pipes is not sufficient to warrant the assumption by the general public of the expense incident to furnishing them with water.

In regard to the third, the service rendered in supplying water for fire purposes only for private fire pipes, merits compensation.

In regard to the fourth, securing assurance of the use of private fire pipes for such purposes only is a matter of small expense, and may reasonably be required.

The cost of private fire protection may reasonably be estimated at a certain proportion of the total cost of fire protection; which latter often falls between one third and one half the total maintenance account, interest included.

The value of the protection afforded is many times its cost, and should be assessed upon those directly benefited. A percentage of the insurance premiums paid will, in many cases, furnish a satisfactory method.

In some cases it may be well to recognize the different fire protective efficiency due to different pressures. It is, of course, desirable that a rate be in proportion to the value of the service rendered. In case, however, of private fire protection, a very close approximation to such a rate it is next to impossible to determine without the coöperation of parties too deeply interested to admit of fair and unbiased action on their part. In public works, too, the charges are, and we think are liable for some time

to remain, so small a proportion of the value of the service that extreme accuracy in the detail of minimum assessment is uncalled for.

A minimum rate based upon the size of the service, in so far as the size influences the value to the user, the cost of maintenance and supervision, and the risk entailed upon other interests, somewhat in the following proportion, would be reasonable.

Taking a 6-inch service, without other information in regard to its use or other means of control than the assurance of the owner that it is used for no other than fire purposes, as a standard for comparison, minimum prices for fire protection in the following proportion would not be unreasonable.

	Size not limited. No definite control.	*Size limited. No definite control.*	*Size not limited but controlled.*	*Size limited and controlled.*
6-inch,	100%	75%	60%	40%
4-inch,	50%	35%	30%	20%
3-inch,	25%	20%	15%	15%
2-inch or less,	20%	15%	10%	10%

Larger services, proportionately larger prices.

Each of the above percentages has reference to the price established under the particular prevailing conditions for a 6-inch service understood to be used for fire purposes only, with no other information in regard to, or means of control of, its use than the assurance of its owner that it is used for such purposes only.

While a generally applicable rate or method of assessment is not to be expected, for minimum rates prices for less than which services of the sizes and under the conditions named will not be furnished, in the above proportion will ordinarily be found reasonable.

For water actually used to put out a fire, no additional charge over and above the minimum charge for fire protection, is contemplated.

We would direct attention to the recommendations of the American Water Works Association in regard to this matter, promulgated at their recent meeting in Chicago.*

This report, Mr. J. M. Diven, secretary of the American Water Works Association, informs us, was unanimously adopted by that association.

We heartily commend the action taken by the American Association, but would amend the first, fourth, and seventh paragraphs to read as follows:

First. That all applications for attachments to street mains for private fire service be accompanied by a draft or plan of the proposed pipe system intended to be used upon the property to be protected, together with an agreement that the service applied for shall be used for no other than fire purposes.

Fourth. That the attempt to secure large services for fire or other purposes, without furnishing reasonably trustworthy evidence in regard to the method of their use, is unreasonable, and should not be permitted by the purveyors of water and fire protection, whether acting for public or private corporations.

Seventh. That to avoid the surreptitious use of water, services unprovided with suitable devices for determining with reasonable accuracy the method of their use be not permitted.

A metered by-pass around a butterfly valve, arranged to automatically open and become locked open on a drop of pressure on its outlet side, or a metered by-pass around a weighted swing check, opening toward the private system in such manner as to throw its weight and become locked open upon a drop in pressure on its outlet side, or such unautomatic device as is in use at Wilkinsburg, Pa., may, without at all impairing the fire protective

* See page 303.

efficiency of the service, if permitted, furnish reasonably trustworthy information in regard to the use of a service used for fire purposes only.

The espionage necessary to insure the use of private fire services for no other than fire purposes is irksome to both the inspector and the inspected, and its long continuance is impracticable.

There are fewer places now than formerly where a small favored class get their water for about one fifth of the rate charged the general public, and a much better fire protection for the same rate as that charged the general public.

Though there is no more justice in the very small taker getting his service at less than cost and at the expense of the larger takers than there is for the large takers getting their supply at less than cost and at the expense of the smaller takers, the fact that the latter has frequently in former years been the case, both as regards fire protection and water supply, affords the reason for the present reaction in the former direction.

Where a charge for private fire protection is made, it is ordinarily less than one tenth the value of the protection afforded. In our opinion those who oppose so reasonable a charge for private fire protection are standing in their own light, for with schedule rates free lists are becoming out of date, and if "you can't fool all of the people all of the time," a charge seems to us inevitable. It is to be hoped that a happy and equitable mean may be reached.

We would recommend that, provided trustworthy evidence in regard to the use of the service and reasonable remuneration for the protection afforded be furnished, such applications for private fire services as will not unwarrantably jeopardize other interests be granted.

APPENDIX B.

Statement of Conditions and Conclusions submitted by Messrs. French, Fiske, and Cook, to the Fire Pipe Committee, giving more fully the reasons for the Conclusions in the Report which they submitted to the Association, and also somewhat extending the Data as to Cost, Value, etc., of Private Fire Protection.

In this statement, the questions given were those originally submitted to the Committee, and have been taken up in this case as they furnished convenient subdivisions of the whole problem.

First. "Whether the opportunities for the taking of water without the knowledge of the water department afforded by the presence of private fire pipes are frequently taken advantage of or no": —

We have found that the manufacturing plants having private fire protection supplied with water from the public mains may be divided into three general classes: First, there are those with unscrupulous management who deliberately, even to the extent of making secret connections, take the public water in quantities as desired, with the avowed intention of getting something which they need for nothing. We think this class is not very large, but they furnish the more glaring examples of the abuse of fire systems, and they contribute largely to the suspicion with which the fire service is often looked upon by the water-works superintendent. Second, we have a class which, we believe, includes the greater part of all the cases where private fire supplies are improperly used, where there is no actual intention to defraud the public, but where, through thoughtlessness or from a lack of reasonable appreciation of the rights in the case, water is taken now and then from the fire system for any pressing need. In general, in such cases the chief motive is to quickly get a supply of water when an *extra* amount is needed, or when the ordinary supply, such as the mill pumps, happens to fail. Convenience, therefore, is the guiding feature, and where the propriety of such takings is considered at all, the action is justified by the feeling that the water is so very cheap that to take some now and then cannot be wrong when it is for an emergency. The third class comprises the risks which have very scrupulous management, or which, from training, have learned that such takings of water are very much objected to by the water department, and always, when discovered, bring an earnest protest, so that, from years of such schooling it is generally understood by every one on the premises that water must not be taken from the fire mains except for fire purposes.

The first class may take much or little, depending on their needs and their daring. The second usually have to draw the water from some special connection made for the purpose, as by attaching a hose line to a nearby hydrant or sprinkler drain valve, or in some other way, making the taking more or less of a temporary affair which, in most cases, would naturally be discontinued as soon as the unusual demand were over or the normal supply restored. Such takers may use considerable water in one emergency if their needs happen to be great, but probably such users of water would not in a year take a *total* number of gallons which would be more than a small percentage of the consumption of the community at large. In the case of the first or the second class of concerns there may be some waste of water from the fire system, due to leakage, which, where the management was either unscrupulous or lax, might be allowed to go on for a considerable time without remedy.

Deliberate stealing of water should be punished the same as any other

stealing whenever detected. The thoughtless taking of water should be stopped whenever found, and the offending concern made to pay a good price for whatever they may have used, the amount being estimated as closely as possible under the conditions. It should be very clearly pointed out to such managers that the taking of water in this way is absolutely wrong, and that the large mill has no more right to use the public water without paying for it than has the smallest householder.

Outside of the question of right and wrong, even if large total amounts of water are not taken, it does often happen that occasional draughts of this kind are at such a high rate of flow as to make undesirable disturbances in pressure in the system, which may be mistaken for breaks, thus giving the superintendent a good deal of trouble and anxiety. Further, they all add an element of uncertainty always annoying, and especially so in those cases where a superintendent is earnestly endeavoring to account for practically all of the water pumped.

Second. "Whether the benefit to the general public from the presence of private fire pipes is sufficient to warrant the assumption by the general public of the expense incident to furnishing them with water, or no": —

We believe that private fire protection is in several ways a benefit to the general community. This being the case, we believe there is a sort of moral obligation, if not an actual legal one, to supply such systems from the public mains, and that, in most cases, it is the best of business policy on the part of the public to do this.

The expense to the general public would usually be nothing beyond the expense which would ordinarily be considered proper in providing water mains and hydrants in the streets surrounding the manufacturing property in question.

The above is based on the understanding that the cost of connecting the private system with the public mains will be borne by the protected plant; that some means entirely satisfactory to the water-works superintendent will be provided to insure that no water is used through the fire system for any purpose other than for fire, and that a yearly payment be made, sufficient to cover the cost to the water department of maintaining the necessary supervision. This supervision would probably come in some one of the ways to be suggested later, or in some better method which may eventually be developed.

Our reasons for believing that private fire systems are a benefit to the public are as follows: —

(*a*) A serious fire in a prosperous manufacturing concern is often a direct injury to a town or city, because such a fire, if only a partial destruction occurs, may throw a number of hands out of employment for several months, thus causing a direct loss to the community in wages earned. Again, if the fire is more serious and cripples the business entirely, the result may be, in these days of consolidation, the moving away of a valuable industry when a new plant is to be constructed somewhere. Further, a severe fire may easily spread and do damage to surrounding property.

(*b*) Good private protection, meaning complete sprinklers as well as pumps and yard hydrants, greatly reduces the chance of such a severe fire and renders the total destruction of the plant almost impossible.

This is because the sprinklers, covering every point, stand ready to put water on a fire night or day at the very instant that it starts. Further, conveniently located yard hydrants permit bringing powerful fire streams through short lines of hose quickly into use. The private system, therefore, uses the available water more surely and efficiently than is possible when depending upon street hydrants and a public department only, so that much less water is actually used than if there were no private system.

Therefore, we have considered that private protection is a benefit to the general public.

Our reasons for believing that there is a sort of moral obligation, and that it is good business policy to supply such private systems from the public mains, are as follows: —

(*a*) It has become the general custom for towns and cities to lay out their water systems with the idea of providing sufficient water for fighting fires, and then to provide public fire departments to use this water. The public, therefore, have, as it were, freely accepted the responsibility of extinguishing fires whenever they occur, using water and fire departments to their fullest extent for this purpose. It is also universally understood that any taxpayer is entitled to this protection.

(*b*) Private fire systems, as already fully explained, greatly reduce the chance of serious fires by providing extinguishing apparatus, which is even more efficient than that found in the best-equipped public fire departments.

(*c*) Such private protection costs from three to five per cent. of the destructible value of a manufacturing plant, and this expense is borne entirely by the owners of the protected property.

Therefore, owners of a manufacturing property who put in complete private protection are directly aiding the general public in meeting the common responsibility to guard against fire hazard. At their own expense they provide better tools for the public water to work with. For these reasons we have felt that it was good business policy to encourage owners to so protect their plants, and that it was only fair to permit the man who provides more efficient apparatus than that which the public can furnish to have ample water — always under proper regulations — to use through his apparatus when a fire comes.

Third. "Whether the service rendered in supplying water for fire purposes only to private fire pipes merits compensation or no": —

With all first cost of installation paid by the mill, and with a satisfactory guarantee in some way that water will be used through the fire service for fire purposes only, and with a well-laid-out system, having no greater chances for dangerous breaks than exist in any other part of the water-works system, and with a yearly payment proportioned to perfectly reimburse the public departments for reasonable supervision over the fire service, we believe that no further compensation is warranted. The reasons for this conclusion are fully given in answer to the second question.

Fourth. "Whether securing assurance of the use of private fire pipes for such purposes only is merely a matter of a few dollars, and may reasonably be required or no": —

We believe that assurance can be secured as to the use of water through private fire supplies at moderate expense, though no one thoroughly satisfactory method, applicable to all cases, is yet available. We have considered the following plans, one plan being the best for one place, another for another, and so on, letting the special conditions existing be the determining factor in each case: —

(*a*) *Simple Lay-out and Inspection.*

With small manufacturing plants, having a simple fire system entirely separate from pipes carrying water for manufacturing uses, and laid out in a direct and straightforward manner, so that the water-works inspector can quickly become entirely familiar with every part of it, and with mill yards so open that water could not be used to any extent without attracting attention, we are inclined to think that no further protection other than periodical inspections and a clear understanding with the mill management would in most cases be necessary. Simplicity is best where it is good enough, so that in such cases we would rather advise against additional apparatus.

(*b*) *Small Detector Meter in By-pass around Main Gate.*

In some cases a ⅝-inch by-pass has been piped around the main gate at

the entrance to the mill yard and provided with connections for quickly connecting in a ⅝-inch meter. The water-works superintendent, or one of his assistants, would then once in a while slip a meter into this connection and close the main gate without giving any previous notice to the mill people. If the small meter began to move, it was an indication that water was being used, and investigation followed, and the trouble was at once sought out. This plan requires a little time now and then, but gives a superintendent easy means of watching his fire supplies, and, after a few cases of violation, results in making the mill people much more careful. The water should, of course, be kept shut off for only a few minutes, and a man should remain at the gate ready to open it instantly if a fire should occur.

Coming now to the cases where the water-works superintendent feels that some permanent and positive device is necessary on the fire service, the following plans have been considered: —

(*c*) *Ordinary Meters.*

Some one of the regular commercial meters would naturally first be thought of in such a case, but, practically, none of the ordinary types are really satisfactory for this work. Piston or disk meters considerably obstruct the flow, and if their moving parts become blocked may almost entirely cut off the water. The current type of meter introduces less obstruction but is not satisfactory to many water-works superintendents from its inability to detect the smallest flows. Again, the fish traps used with most meters are very likely to become seriously clogged by leaves, pipe scales, etc., which are apt to be brought along by the scouring action of the very heavy draughts caused by fire duty.

(*d*) *Sealing Hydrants and Valves.*

This plan has been quite successfully carried out in New Bedford, Providence, and some other places, and provides for sealing all hydrants and sprinkler drain valves. The seals are put on by the water department, to be broken only in case of fire, a fine being imposed for breaks at other times which cannot be satisfactorily explained. With a well-arranged public water department, this system will generally work satisfactorily. It does not, of course, detect concealed taps made by unscrupulous persons, but does provide against all ordinary takings.

From the underwriters' standpoint such sealing is not wholly desirable, and its general introduction throughout all private systems would be looked upon as unfortunate. This is from the fact that sealing tends to take the responsibility for the fire apparatus away from the mill force and leads them to rely more and more on the public fire department. Experience has shown the underwriters that good mill fire brigades are desirable even where there is an efficient public fire department, as the mill brigade, knowing the ins and outs of the mill buildings better, can often extinguish small fires with less loss on account of this knowledge, and further, every once in a while they are found absolutely necessary to guard the mill property when public departments are using their entire force and energies on a severe fire outside of the mill yard. Anything, therefore, which takes incentive from the mill brigade is somewhat undesirable.

(*e*) *Proportional Meters.*

In this type of measuring device a small meter — one-, two-, or three-inch — is put in a by-pass around an ordinary check valve, the clapper of which is perhaps weighted. Such devices, we believe, have promising possibilities. We have considerable data at our disposal on tests of meters of this kind. We have not as yet had time to develop what we believe is the ideal arrangement, but, even with present data, a metering device can be laid out which will detect very small flows, and which will give a fairly good measure of the water which passes through it. After some additional investigation we think it altogether probable that we could make definite

suggestions and furnish sketches for such meters, under different conditions, which would produce devices that would be satisfactory to the water-works superintendent and entirely unobjectionable to the insurance interests, and which would be serviceable in a great many cases where a permanent metering device or detecting device of some kind is desired.

There are several other devices of special design which have been suggested, but which as yet have not been fully investigated. It seems altogether probable that along some of these lines will be found a metering device which will be entirely satisfactory and in every way unobjectionable. Such a device would go a long way towards solving this problem, and it is earnestly hoped that further encouragement may be given to such investigation.

Fifth. "Any other facts in regard to private fire pipes, the manner of their use, the value and cost of the protection afforded, upon whom and how the cost of such protection should be assessed, etc., which the Committee may see fit to present": —

(*a*) *Manner of Use.*

All extensive private fire systems are laid out by the engineering departments of insurance associations in coöperation with the engineer of the mill. The underlying principle is to secure the simplest possible arrangement of the fire pipes. Outside gates with indicator posts are provided on all connections going outside of buildings. The aim is to locate these so that they will be surely accessible under any condition of fire, thus making it possible to cut off a broken connection and save the waste of water. The underwriters always require, where it is possible, the absolute separation of the pipes used for mill supply water from the fire systems. Protected mills are usually in a selected class and receive regular inspection, thus tending to keep the fire apparatus in reasonably good order. The underwriters always advise that the requirements of the public water departments be carefully ascertained and strictly lived up to, and that plans of the proposed private system be submitted to the water department whenever they desire them. In general the underwriters desire a yearly test of the yard system, putting on several lines of hose and running water for a few minutes, the idea being to represent actual fire conditions and ascertain that the whole system is in proper working order. This test often discloses partly closed gates, thus showing the value of periodic testing. The underwriters always advise making such tests strictly under whatever regulations may be made by the water department as to testing, and their inspectors are instructed to carefully follow all requirements thus laid down, giving notice to the water department in advance of testing wherever it is desired.

(*b*) *Cost of Protection.*

Modern protection means automatic sprinklers throughout practically all buildings, a good supply for these sprinklers from public mains or private elevated tanks of large size, and a secondary supply, generally from fire pumps. Pipes are then laid through the yards to supply the sprinkler connections and private hydrants. The cost of such equipment averages from three to five per cent. of the total value of the property which could be destroyed by fire. A modern manufacturing plant of moderate size is easily worth $300,000, so that the protection of such a property would ordinarily cost from $9,000 to $15,000. This cost is entirely borne by the owners of the manufacturing concern, and in addition to it there is, of course, a constant annual cost of moderate amount for keeping the system in first-class condition all the time.

(*c*) *The Value of Protection.*

The value of protection comes first from its efficiency in reducing the great annual fire waste of the country, and second from the freedom from

interruption of business which a bad fire always causes. The annual fire loss in the United States is from $100,000,000 to $200,000,000. This means so much actual value burned up, and this loss is paid for in the long run by the community at large. Each one of us contributes his small share. The insurance companies are the means by which this great loss is distributed over the whole community in a fairly uniform manner, so that no one of us feels his contribution very heavily, but we are none the less the losers and would be just this amount better off if the fire waste could be stopped.

The efficacy of protection in preventing these wastes is shown by the figures for the year 1900 for a group of protected risks. This group consisted of concerns manufacturing cotton and woolen goods, paper and general metal work, with an aggregate value of about $900,000,000. Four hundred and fifty fires were reported, with a total loss of only $550,000. Of the 450 fires, 379 occasioned the loss of less than $1,000 each ; 59 less than $10,000 each, and only 12 caused a loss of over $10,000 each. In the case of the 12 fires where the loss was over $10,000, there was in every case some peculiar condition,—either deficiency in protection, or some accidental feature which allowed the fire to cause excessive damage.

When it is considered that many of these risks have inflammable stock like cotton, and that they all contain large amounts of fast-moving machinery, so that under ordinary conditions many fires and large losses would be expected, it is seen how very efficient good private protection can be, and how great its value is as a means of preventing our enormous annual fire wastes.

(*d*) *Upon Whom and How the Cost of Protection should be Assessed.*

We have already seen that the first cost of the private protected equipment is entirely borne by the owners of the protected plant, that the first cost and all cost of making connection to the public mains is borne by the owners of the protected plants, and that the owners should pay a yearly amount sufficient to completely reimburse the public water department for all reasonable cost in so supervising private fire service that they may ensure its use for fire fighting only. We believe that it is right and proper that all of these costs should be paid entirely by the private protected plant. This leaves no expense to the public department except the laying of water mains and the providing of hydrants in the streets around protected property, a work which they would ordinarily be expected to do entirely regardless of whether the manufacturing plant has private protection or not. Street mains sufficient for the reasonable protection of a property would ordinarily be sufficient to give ample supply to any private equipment, so that, in general, the private equipment makes no requirement on the public in addition to what the public would ordinarily be expected to do for any taxpaying property.

We believe the above covers all cases except the occasional one where a large manufacturing plant is located well beyond the limits of the public water supply, but still within the bounds of the town or city. In such cases we believe it reasonable, where conditions will allow, to extend the public water supply to the manufacturing plant, but to apply exactly the same rule as is applied to the extension of water mains into any district as yet thinly built up, namely, to assess a yearly charge on the manufacturing plant sufficient to pay a fair interest on the cost of the pipe extension, allowing this charge to be eventually eliminated if the natural building up in the vicinity brings an equivalent revenue from ordinary water takers. This is simply the application of an old-established rule, and we believe it is just as fair for the large manufacturing plant as it is for the one or two small householders who build beyond the limits of the water supply. Of course, if the manufacturing plant in question desired to use a considerable amount of public water at regular meter rates this, in itself, would often justify the extension outside of the fire protection question.

FINAL REPORT OF THE COMMITTEE ON STANDARD SPECIFICATIONS FOR CAST-IRON PIPE.*

FREEMAN C. COFFIN, DEXTER BRACKETT, F. F. FORBES, COMMITTEE.

[*Presented September 10, 1902.*]

BOSTON, September 1, 1902.

TO THE NEW ENGLAND WATER WORKS ASSOCIATION:

Gentlemen, — Nine months have passed since your Committee made its preliminary report and offered a draft of Standard Specifications for your consideration. The subject was discussed at two public meetings of the Association, and a number of written communications were read, all of which have been published in the JOURNAL. The Committee has since earnestly sought for other suggestions from those interested in the subject, particularly from experienced pipe inspectors, whose long practice at different foundries has given them an intimate acquaintance with the methods of making cast-iron pipe, and whose suggestions the Committee has found valuable.

The greatest cause of delay in the making of a final report has been the consideration of the subject with a committee which represents, to a large extent, the pipe foundries of the country. This committee began its consideration of the subject soon after the presentation of the report of your Committee on December 11, 1901. Their conclusions and propositions, which were issued in a printed pamphlet, and which are published as an appendix to this report, were not received by your Committee until June 4, 1902. This is not said in any spirit of complaint of the manufacturers' committee, but quite the contrary, as your Committee wishes to express its great satisfaction that the action of this Association in proposing Standard Specifications for cast-iron pipe should be considered a matter of such importance to the manufacturers of pipe that they were willing to spend the time and money necessary for so thorough a study of

* See Preliminary Report of the Committee, with Discussion, on page 85 of the JOURNAL (June, 1902).

the matter among themselves. This fact and the interest shown in our action by other associations of a like nature to our own, not only in this country but in England, that through their representatives have given the Committee their assurance of a willingness and desire to coöperate with us, has been of great encouragement to your Committee to persevere when at times its success in finally attaining a satisfactory result seemed uncertain.

After receiving the report of the committee of the pipe manufacturers and giving it careful consideration, a conference was arranged with a sub-committee consisting of Messrs. Walter Wood, L. R. Lemoine, A. H. McNeal, G. J. Long, A. C. Overholt. These gentlemen met your Committee in Boston. coming here twice for that purpose. Altogether we had four sessions of several hours each, spent in discussing all of the points relating to the manufacture of pipe and the bearing of the different clauses of the proposed specifications upon them.

In these conferences each committee naturally looked at the subject from its own point of view, on one side the manufacturers seeking to provide for the practice that would occasion the fewest difficulties in the foundries and secure a minimum of cost in the product, so far as consistent with good quality; on the other, your Committee seeking to secure the best possible pipe, made in a way to give the least trouble in its use, also at the lowest cost compatible with these requirements. The several points were very fully discussed, and it is the belief of your Committee that the net result was an endeavor to eliminate such requirements as would result in excessive cost of manufacture without a corresponding increase in quality of the pipe or facility in its use, and to retain all requirements tending to secure actual benefits to the users of pipe, your Committee believing that the consumers can well afford to pay any small difference in cost which may be necessary to secure such benefits.

While your Committee conceded some of the changes in the preliminary specifications asked for by the manufacturers, and met them part way on other points, there were still a few which it did not feel that it was wise to change and upon which it cannot be said that the conference came to an entire agreement. It is hoped, however, that these points of difference will not stand in the way of a cordial acceptance of the specifications by the manufacturers, and that they will be adopted as the basis of general practice in the manufacture

of stock pipe, as it was intimated that they would be, if an agreement was reached.

The provision of the specifications which caused the most debate was the one which was perhaps the most favorably commented upon by those of our members taking part in the discussion already published in the JOURNAL, namely, the proposition to make all pipe of the same nominal size, of a uniform outside diameter. It seemed to the Committee that this change would be acceptable to the manufacturers on account of the reduction in the number of patterns required. During the consideration of this subject in the conference referred to, it was made clear to your Committee that the saving in the patterns for the outside of the pipe was a small matter compared with the vastly increased number of fittings which would be required for the casting of the inside of the socket of the pipe where the inside diameter varies with each class. There was besides a danger that the pipes would be of poor quality if too great difference in the thickness of the pipe were made by increasing the thickness of the clay on the core.

It would require too much space to explain this matter in detail here, but your Committee became fully satisfied that, in order to secure uniformly good pipe without a large increase in cost, it would be necessary to modify the design of the pipe as given in tables Nos. 1 and 2 of the preliminary specifications. Wishing to retain the advantages of a single class of special castings for all of the classes of the smaller sizes of pipe, and the possibility of using the pipe interchangeably, it has revised tables Nos. 1 and 2 in such a manner that there are two patterns of outside diameter for all sizes of pipe from four inches to sixteen inches inclusive, with one class of special castings; three patterns for all sizes of pipe from eighteen inches to sixty inches inclusive, with two classes of special castings for sizes eighteen inches to twenty-four inches inclusive, one for the light and ordinary weights of pipe and another for the heavier weights, and three classes of special castings for the larger sizes.

The different classes for each pattern are obtained by making the outside diameter equal to the nominal diameter plus twice the thickness of the heaviest class of that pattern, and the pipe of the heaviest class have the inside diameter equal to the nominal diameter and a uniform thickness from end to end. The lighter classes are obtained by reducing the thickness of the shell on the inside, except at the extreme ends, where it is to be the same as in the heaviest

class and tapered to meet the thinner portion of the body of the pipe through a length of six inches.

It may be said that this design will result in a pipe line for the lighter classes which is not uniform in inside diameter from end to end. The Committee have considered this matter of the enlargement of the body of the pipe, and, in view of the many uncertain conditions which necessarily exist in all pipe lines, especially when they are not new, is of the opinion that the effect is inconsiderable and, whatever it may be, is on the side of increased capacity. In any event, this method of manufacture is the only practicable one, in the opinion of your Committee, by which pipes can be made which are interchangeable and which can be used satisfactorily with one pattern of special casting up to sixteen inches in diameter.

Note. — It may be said in reply to the last statement that some cities are having all of their pipes cast with uniform outside diameters. This is true, and attention is called to the fact that the range of weight or thickness used by any single city is much narrower than that provided for in the tables of these specifications, which are designed to meet the requirements of all users of water pipes, and necessarily cover what some consider very light pipe and what others consider very heavy. The Committee believes this range of design to be necessary, and wishes to emphasize its conviction that it is not the province of Standard Specifications to dictate engineering design.

To use one pattern of special castings with two patterns of pipe, the joint room for the larger pattern is made a little thinner than the standard joint of the pipes and a little thicker for the smaller pattern. No joint room, however, is less than .35 of an inch, and none exceeds .60 of an inch. As the special castings occur only occasionally in the line, the above variation in joint room cannot be a serious matter, particularly when we consider past experience in this respect.

All suggestions made in the discussion of the subject have been carefully considered by your Committee, and many of them incorporated in the final form of the specifications now presented. These may be readily found by comparison with the preliminary specifications, as well as the changes made at the request of the manufacturers' committee, and it seems unnecessary to occupy time and space to refer to them in detail.

So much time has been occupied in the consideration of the specifications that your Committee was not able to submit at the present

time tables showing the design and standard weights of the several classes and patterns of special castings.

In general design the special castings recommended are of the pattern now used on the Metropolitan Water Works. If these specifications are adopted by the Association, tables giving the dimensions and weight of every special casting required in ordinary practice will be prepared by your Committee, to be published with the specifications in their final form.

Respectfully submitted,

FREEMAN C. COFFIN,
DEXTER BRACKETT,
F. F. FORBES,

Committee on Standard Specifications for Cast-Iron Pipe.

NOTE.— Many of these tables have since been prepared and are now printed with the specifications. The remainder of the tables are expected to be ready for publication in the next issue of the JOURNAL. The specifications with the complete tables will then be reprinted, and will be for sale by the Secretary.

DECEMBER 1, 1902.

PROPOSED SPECIFICATIONS.

NEW ENGLAND WATER WORKS ASSOCIATION STANDARD SPECIFICATIONS FOR CAST-IRON PIPE.

Description of Pipes.

SECTION 1. The pipes shall be made with hub and spigot joints, and shall accurately conform to the dimensions given in tables Nos. 1 and 2. They shall be straight and shall be true circles in section, with their inner and outer surfaces concentric, and shall be of the specified dimensions in outside diameter. They shall be at least twelve feet in length, exclusive of socket. For pipes of each size from 4 inches to 16 inches in diameter there shall be two standards, and for each larger size three standards of outside diameter. The inside diameter of each class shall be increased from the nominal size in the manner hereinafter specified, so as to obtain the standard thickness and weight. For pipes from 4 inches to 16 inches in diameter one class of special castings shall be furnished with all classes of pipes. For pipes from 18 inches to 24 inches in diameter, Class D special castings shall be furnished with pipes of Classes A, B, C, and D, and Class F special castings with pipes of Classes E and F. For pipes 30 inches in diameter and larger, Class B special castings shall be used with pipes of Classes A and B, Class D special castings with pipes of Classes C and D, and Class F special castings with pipes of Classes E and F.

All pipes having the same outside diameter shall have the same inside diameter at both ends. The inside diameter of the lighter pipes of each standard outside diameter shall be gradually increased for a distance of six inches from each end of the pipe, so as to obtain the required standard thickness and weight for each size and class of pipe.

Allowable Variation in Diameter of Pipes and Sockets.

SECT. 2. Especial care shall be taken to have the sockets of the required size. The sockets and spigots will be tested by circular

gages, and no pipe will be received which is defective in joint-room from any cause. The diameters of the sockets and the outside diameters of the spigot ends of the pipes shall not vary from the standard dimensions by more than .06 of an inch for pipes 16 inches or less in diameter; .08 of an inch for 18-inch, 20-inch, and 24-inch pipes; .10 of an inch for 30-inch, 36-inch, and 42-inch pipes, and .12 of an inch for 48-inch, 54-inch, and 60-inch pipes.

Allowable Variation in Thickness.

SECT. 3. For pipes whose standard thickness is less than one inch, the thickness of metal in the body of the pipe shall not be more than .08 of an inch less than the standard thickness, and for pipes whose standard thickness is one inch or more, the variation shall not exceed .10 of an inch, except that for spaces not exceeding eight inches in length in any direction, variations from the standard thickness of .02 of an inch in excess of the allowances above given shall be permitted.

Defective Spigots may be Cut.

SECT. 4. Defective spigot ends on pipes twelve inches or more in diameter may be cut off in a lathe, and a half-round wrought-iron band shrunk into a groove cut in the end of the pipe. Not more than twelve per cent. of the total number of accepted pipes of each size shall be cut and banded, and no pipe shall be banded which is less than eleven feet in length, exclusive of the socket.

In case the length of a pipe differs from twelve feet, the standard weight of the pipe given in Table No. 2 shall be modified in accordance therewith.

Special Castings.

SECT. 5. All special castings shall be made in accordance with the cuts and the dimensions given in the tables forming a part of these specifications.

The diameters of the sockets and the external diameters of the spigot ends of the special castings shall not vary from the standard dimensions by more than .08 of an inch for castings 16 inches or less in diameter; .10 of an inch for 18-inch, 20-inch, and 24-inch pipes; .13 of an inch for 30-inch, 36-inch, and 42-inch pipes, and .16 of an inch for 48-inch, 54-inch, and 60-inch pipes.

The flanges on all manhole castings and manhole covers shall be

faced true and smooth, and drilled to receive bolts of the sizes given in the tables. The contractor shall furnish and deliver all bolts for bolting on the manhole covers, the bolts to be of the sizes shown on plans, and made of the best quality of mild steel, with hexagonal heads and nuts, and sound, well-fitting threads.

Marking.

SECT. 6. Every pipe and special casting shall have distinctly cast upon it the initials of the maker's name. When cast especially to order, each pipe and special casting shall also have cast upon it figures showing the year in which it was cast and a number signifying the order in point of time in which it was cast, the figures denoting the year being above and the number below; thus, —

1901	1901	1901
1	2	3

etc., also any initials, not exceeding four, which may be required by the purchaser. The letters and figures shall be cast on the outside and shall be not less than two inches in length and one-eighth of an inch in relief for pipes eight inches in diameter and larger. For smaller sizes of pipes the letters may be one inch in length. The weight and the class letter shall be conspicuously painted in white on the inside of each pipe and special casting after the coating has become hard.

Allowable Percentage of Variation in Weight.

SECT. 7. No pipe shall be accepted the weight of which shall be less than the standard weight by more than five per cent. for pipes sixteen inches or less in diameter, and four per cent. for pipes more than sixteen inches in diameter; and no excess above the standard weight of more than the given percentages for the several sizes shall be paid for. The total weight to be paid for shall not exceed for each size and class of pipe received the sum of the standard weights of the same number of pieces of the given size and class by more than two per cent.

No special casting shall be accepted the weight of which shall be less than the standard weight by more than ten per cent. for pipes twelve inches or less in diameter and eight per cent. for larger sizes; and no excess above the standard weight of more than the above percentages for the several sizes will be paid for.

Quality of Iron.

Sect. 8. All pipes and special castings shall be made of cast iron of good quality, and of such character as shall make the metal of the castings strong, tough, and of even grain, and soft enough to satisfactorily admit of drilling and cutting. The metal shall be made without any admixture of cinder iron or other inferior metal, and shall be remelted in a cupola or air furnace.

Tests of Material.

Sect. 9. Specimen bars of the metal used, each being 26 inches long by 2 inches wide and 1 inch thick, shall be made without charge as often as the engineer may direct, and in default of definite instructions the contractor shall make and test at least one bar from each heat or run of metal. The bars, when placed flatwise upon supports 24 inches apart and loaded in the center, shall for pipes 12 inches or less in diameter support a load of 1 900 pounds and show a deflection of not less than .30 of an inch before breaking, and for pipes of sizes larger than 12 inches shall support a load of 2 000 pounds and show a deflection of not less than .32 of an inch. The contractor shall have the right to make and break three bars from each heat or run of metal, and the test shall be based upon the average results of the three bars. Should the dimensions of the bars differ from those above given, a proper allowance therefor shall be made in the results of the tests.

Casting of Pipes.

Sect. 10. The straight pipes shall be cast in dry sand molds in a vertical position. Pipes sixteen inches or less in diameter shall be cast with the hub end up or down, as specified in the proposal. Pipes eighteen inches or more in diameter shall be cast with the hub end down.

The pipes shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal contraction by subsequent exposure.

Quality of Castings.

Sect. 11. The pipes and special castings shall be smooth, free from scales, lumps, blisters, sand holes, and defects of every nature

which, in the opinion of the engineer, unfit them for the use for which they are intended. No plugging or filling will be allowed.

Cleaning and Inspection.

SECT. 12. All pipes and special castings shall be thoroughly cleaned and subjected to a careful hammer inspection. No casting shall be coated unless entirely clean and free from rust, and approved in these respects by the engineer immediately before being dipped.

Coating.

SECT. 13. Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle, nor with any tendency to scale off.

Each casting shall be heated to a temperature of 300° Fahrenheit immediately before it is dipped, and shall possess not less than this temperature at the time it is put in the vat. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

The varnish shall be heated to a temperature of 300° Fahrenheit (or less, if the engineer shall so order), and shall be maintained at this temperature during the time the casting is immersed.

Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated, the pipes shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be recoated shall first be thoroughly scraped and cleaned.

Hydrostatic Test.

SECT. 14. When the coating has become hard, the straight pipes shall be subjected to a proof by hydrostatic pressure, and, if required by the engineer, they shall also be subjected to a hammer test under this pressure.

The pressures to which the different sizes and classes of pipes shall be subjected are as follows: —

	20-inch Diameter and Larger. Pounds per Sq. In.	Less than 20-inch Diameter. Pounds per Sq. In.
Class A pipe	150	300
Class B pipe	200	300
Class C pipe	250	300
Class D pipe	300	300
Classes E to K pipe, inclusive	350	350

Weighing.

SECT. 15. The pipes and special castings shall be weighed for payment under the supervision of the engineer, after the application of the coal-tar pitch varnish. If desired by the engineer, the pipes and special castings shall be weighed after their delivery, and the weights so ascertained shall be used in the final settlement, provided such weighing is done by a legalized weighmaster. Bids shall be submitted and a final settlement made upon the basis of a ton of two thousand pounds.

Contractor to Furnish Men and Materials.

SECT. 16. The contractor shall provide all tools, testing machines, materials, and men necessary for the required testing, inspection, and weighing at the foundry of the pipes and special castings; and should the purchaser have no inspector at the works, the contractor shall, if required by the engineer, furnish a sworn statement that all of the tests have been made as specified, this statement to contain the results of the transverse tests upon the test bars.

Power of the Engineer to Inspect.

SECT. 17. The engineer shall be at liberty at all times to inspect the material at the foundry, and the molding, casting, and coating of the pipes and special castings. The forms, sizes, uniformity, and conditions of all pipes and other castings herein referred to shall be subject to his inspection and approval, and he may reject, without

proving, any pipe or other casting which is not in conformity with the specifications or drawings furnished.

Inspector to Report.

SECT. 18. The inspector at the foundry shall report daily to the foundry office all pipes and special castings rejected, with the causes for rejection.

Castings to be Delivered Sound and Perfect.

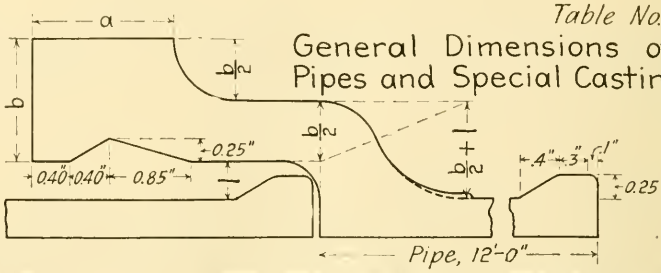
SECT. 19. All the pipes and other castings must be delivered in all respects sound and conformable to these specifications. The inspection shall not relieve the contractor of any of his obligations in this respect, and any defective pipe or other casting which may have passed the engineer at the works or elsewhere shall be at all times liable to rejection when discovered, until the final completion and adjustment of the contract, provided, however, that the contractor shall not be held liable for pipes or special castings found to be cracked after they have been accepted at the agreed point of delivery. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material of any kind shall be placed in the pipes during transportation or at any time after they receive the coating.

Definition of the Word "Engineer."

SECT. 20. Wherever the word "engineer" is used herein, it shall be understood to refer to the engineer or inspector acting for the purchaser, and to his properly authorized agents, limited by the particular duties intrusted to them.

Table No. 1

General Dimensions of Pipes and Special Castings.



Nominal Diam. INCHES	Classes	Actual Outside Diam. INCHES	DIAM. OF SOCKETS Pipe INCHES	DIAM. OF SOCKETS Special Castings INCHES	DEPTH OF SOCKETS Pipe INCHES	DEPTH OF SOCKETS Special Castings INCHES	"a"	"b"
4	A,C,E	4.80	5.60	5.70	3.00	4.00	1.50	1.30
"	G,I,K	5.00	5.80	"	"	"	"	"
6	A,C,E	6.90	7.77	7.80	"	"	"	1.40
"	G,I	7.10	7.90	"	"	"	"	"
8	A,C,E	9.05	9.85	10.00	3.50	"	"	1.50
"	G,I	9.30	10.10	"	"	"	"	"
10	A,B,C,D	11.10	11.90	12.10	"	4.50	"	"
"	E,F,G,H	11.40	12.20	"	"	"	"	"
12	A,B,C,D	13.20	14.00	14.20	"	"	"	1.60
"	E,F,G,H	13.50	14.30	"	"	"	"	"
14	A,B,C,D	15.30	16.10	16.35	"	"	"	1.70
"	E,F,G,H	15.65	16.45	"	"	"	"	"
16	A B C D	17.40	18.40	18.60	4.00	5.00	1.75	1.80
"	E,F,G,H	17.80	18.80	"	"	"	"	"
18	A,B.	19.25	20.25	20.40	"	"	"	1.90
"	C,D	19.50	20.50	"	"	"	"	"
"	E,F	19.70	20.70	20.70	"	"	"	"
20	A,B	21.30	22.30	22.50	"	"	"	2.00
"	C,D	21.60	22.60	"	"	"	"	"
"	E,F	21.90	22.90	23.00	"	"	"	"
24	A,B	25.40	26.40	26.60	"	"	2.00	2.10
"	C,D	25.80	26.80	"	"	"	"	"
"	E,F	26.10	27.10	27.10	"	"	"	"
30	A,B	31.60	32.60	32.60	4.50	"	"	2.30
"	C,D	32.00	33.00	33.00	"	"	"	"
"	E,F	32.40	33.40	33.40	"	"	"	"
36	A,B	37.80	38.80	38.80	"	"	"	2.50
"	C,D	38.30	39.30	39.30	"	"	"	"
"	E,F	38.70	39.70	39.70	"	"	"	"
42	A,B	44.00	45.00	45.00	5.00	"	"	2.80
"	C,D	44.50	45.50	45.50	"	"	"	"
"	E,F	45.10	46.10	46.10	"	"	"	"
48	A,B	50.20	51.20	51.20	"	"	"	3.00
"	C,D	50.80	51.80	51.80	"	"	"	"
"	E,F	51.40	52.40	52.40	"	"	"	"
54	A,B	56.40	57.40	57.40	5.50	5.50	2.25	3.20
"	C,D	57.10	58.10	58.10	"	"	"	"
"	E,F	57.80	58.80	58.80	"	"	"	3.80
60	A,B	62.60	63.60	63.60	"	"	"	3.40
"	C,D	63.40	64.40	64.40	"	"	"	"
"	E,F	64.20	65.20	65.20	"	"	"	4.00

TABLE No. 2

Standard Thicknesses and Weights of Cast Iron Pipes

12 feet in length exclusive of socket

Nominal Diameter of Pipe	Class A Thickness of Shell	Class A Weight per Length	Class B Thickness of Shell	Class B Weight per Length	Class C Thickness of Shell	Class C Weight per Length	Class D Thickness of Shell	Class D Weight per Length	Class E Thickness of Shell	Class E Weight per Length	Class F Thickness of Shell	Class F Weight per Length	Class G Thickness of Shell	Class G Weight per Length	Class H Thickness of Shell	Class H Weight per Length	Class I Thickness of Shell	Class I Weight per Length	Class K Thickness of Shell	Class K Weight per Length
	INCHES	POUNDS	INCHES	POUNDS	INCHES	POUNDS	INCHES	POUNDS	INCHES	POUNDS	INCHES	POUNDS	INCHES	POUNDS	INCHES	POUNDS	INCHES	POUNDS	INCHES	POUNDS
4	.34	200			.36	215			.39	230			.42	250			.45	265	.48	280
6	.38	330			.42	350			.46	380			.50	420			.54	445		
8	.42	475			.48	530			.53	575			.58	640			.63	690		
10	.47	650	.50	680	.53	720	.56	760	.60	810	.63	850	.67	890	.70	935				
12	.49	810	.53	855	.57	910	.61	970	.65	1040	.69	1100	73	1160	.77	1220				
14	.53	1010	.57	1080	.61	1150	.66	1220	.70	1310	.75	1390	.79	1460	.83	1530				
16	.55	1215	.60	1300	.65	1390	.70	1490	.75	1610	.80	1710	.85	1810	.90	1900				
18	.57	1400	.63	1520	.69	1660	.75	1780	.80	1910	.86	2040								
20	.60	1610	.66	1760	.72	1920	.79	2090	.85	2260	.92	2420								
24	.64	2050	72	2290	.80	2550	.88	2780	.95	3000	1.03	3240								
30	.71	2860	.81	3230	.91	3600	1.01	3950	1.10	4340	1.20	4700								
36	.79	3800	.90	4270	1.02	4840	1.13	5310	1.25	5900	1.37	6400								
42	.87	4920	1.00	5560	1.13	6270	1.27	6970	1.40	7720	1.53	8360								
48	.95	6130	1.10	6970	1.25	7920	1.40	8780	1.55	9740	1.70	10600								
54	1.03	7510	1.20	8600	1.37	9800	1.54	10900	1.72	12400	1.90	13500								
60	1.10	8900	1.30	10300	1.50	11900	1.70	13300	1.90	15100	2.10	16500								

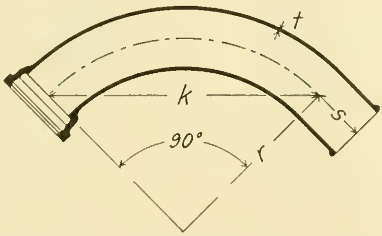
Table No. 3

Straight Pipes
Standard Weights per foot
(exclusive of sockets)

Nominal Diam.	Class	Weight per foot in lbs.	Nominal Diam.	Class	Weight per foot in lbs.	Nominal Diam.	Class	Weight per foot in lbs.
4	A	14.89	14	C	87.97	30	C	277.7
"	C	15.70	"	D	94.85	"	D	307.3
"	E	16.92	"	E	102.73	"	E	338.0
"	G	18.89	"	F	109.70	"	F	367.5
"	I	20.10	"	G	115.24	36	A	287.0
"	K	21.30	"	H	120.74	"	B	326.0
6	A	24.32	16	A	90.98	"	C	373.3
"	C	26.72	"	B	98.95	"	D	412.3
"	E	29.08	"	C	106.9	"	E	459.6
"	G	32.40	"	D	114.8	"	F	502.0
"	I	34.79	"	E	125.5	42	A	368.4
8	A	35.58	"	F	133.5	"	B	422.1
"	C	40.38	"	G	141.4	"	C	481.1
"	E	44.33	"	H	149.3	"	D	538.9
"	G	49.65	18	A	104.5	"	E	600.6
"	I	53.62	"	B	115.2	"	F	654.4
10	A	49.04	"	C	127.4	48	A	459.3
"	B	52.03	"	D	138.0	"	B	530.2
"	C	54.99	"	E	148.4	"	C	608.0
"	D	57.94	"	F	159.0	"	D	678.9
"	E	63.61	20	A	121.9	"	E	758.5
"	F	66.61	"	B	133.7	"	F	829.4
"	G	70.57	"	C	147.6	54	A	559.8
"	H	73.53	"	D	161.4	"	B	650.3
12	A	61.14	"	E	175.6	"	C	749.5
"	B	65.92	"	F	189.5	"	D	839.9
"	C	70.67	24	A	155.6	"	E	946.9
"	D	75.39	"	B	174.4	"	F	1042.7
"	E	81.99	"	C	196.3	60	A	664.0
"	F	86.77	"	D	215.3	"	B	782.3
"	G	91.51	"	E	234.5	"	C	911.5
"	H	96.22	"	F	253.5	"	D	1029.7
14	A	76.85	30	A	215.3	"	E	1162.0
"	B	82.41	"	B	244.8	"	F	1280.0

Table No. 4

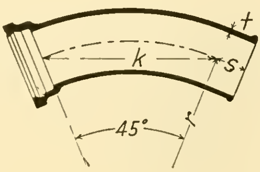
$\frac{1}{4}$ Curves

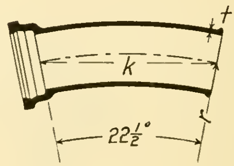


Nominal Diam.	Class	Dimensions in inches t	r	k	s	Weight	
4	K	48	16	22.6	8	80	
6	I	54	"	"	"	130	
8	"	.63	"	"	10	200	
10	H	.70	"	"	12	290	
12	"	.77	"	"	"	375	
14	"	.83	18	25.5	"	500	
16	"	.90	24	34.0	"	740	
18	D	.75	"	"	"	715	
"	F	.86	"	"	"	805	
20	D	79	"	"	"	835	
"	F	.92	"	"	"	950	
24	D	.88	30	42.4	"	1275	
"	F	1.03	"	"	"	1470	
30	B	.81	36	50.9	"	1690	
"	D	1.01	"	"	"	2050	
"	F	1.20	"	"	"	2400	
36	B	.90	48	67.9	"	2750	
"	D	1.13	"	"	"	3380	
"	F	1.37	"	"	"	4040	

Table No. 5

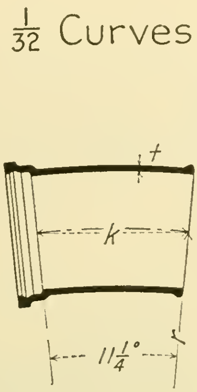
$\frac{1}{8}$ Curves $\frac{1}{16}$ Curves

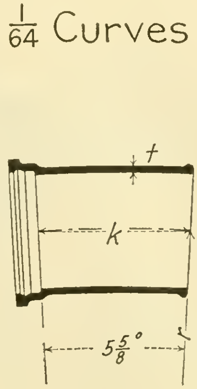




Nominal Diam.	Class	t	$\frac{1}{8}$ Curves				$\frac{1}{16}$ Curves		
			r	k	s	Weight	r	k	Weight
4	K	.48	24	18.4	4	65	48	18.7	55
6	I	.54	"	"	"	100	"	"	90
8	"	.63	"	"	"	150	"	"	130
10	H	.70	"	"	"	200	"	"	175
12	"	.77	"	"	"	260	"	"	225
14	"	.83	36	27.6		375	72	28.1	375
16	"	.90	"	"		475	"	"	475
18	D	.75	"	"		470	"	"	470
"	F	.86	"	"		520	"	"	520
20	D	.79	48	36.7		675	96	37.5	675
"	F	.92	"	"		765	"	"	765
24	D	.88	60	45.9		1060	120	46.8	1060
"	F	1.03	"	"		1210	"	"	1210
30	B	.81	"	"		1250	"	"	1250
"	D	1.01	"	"		1500	"	"	1500
"	F	1.20	"	"		1740	"	"	1740
36	B	.90	90	68.9		2300	180	70.2	2300
"	D	1.13	"	"		2810	"	"	2810
"	F	1.37	"	"		3350	"	"	3350
42	B	1.00	"	"		2980	"	"	2980
"	D	1.27	"	"		3680	"	"	3680
"	F	1.53	"	"		4370	"	"	4370
48	B	1.10	"	"		3740	"	"	3740
"	D	1.40	"	"		4620	"	"	4620
"	F	1.70	"	"		5510	"	"	5510
54	B	1.20	"	"		4630	"	"	4630
"	D	1.54	"	"		5750	"	"	5750
"	F	1.90	"	"		7170	"	"	7170
60	B	1.30	"	"		5550	"	"	5550
"	D	1.70	"	"		7020	"	"	7020
"	F	2.10	"	"		8720	"	"	8720

Table No. 6

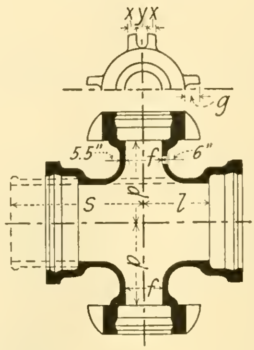




Nominal Diam.	Class	t	$\frac{1}{32}$ Curves			$\frac{1}{64}$ Curves		
			r	k	Weight	r	k	Weight
20	D	.72	240	47.05	750	480	47.10	750
"	F	.92	"	"	920	"	"	920
24	D	.88	"	"	1060	"	"	1060
"	F	1.03	"	"	1215	"	"	1215
30	B	.81	"	"	1250	"	"	1250
"	D	1.01	"	"	1500	"	"	1500
"	F	1.20	"	"	1740	"	"	1740
36	B	.90	"	"	1660	"	"	1660
"	D	1.13	"	"	2000	"	"	2000
"	F	1.37	"	"	2360	"	"	2360
42	B	1.00	"	"	2150	"	"	2150
"	D	1.27	"	"	2620	"	"	2620
"	F	1.53	"	"	3080	"	"	3080
48	B	1.10	"	"	2700	"	"	2700
"	D	1.40	"	"	3300	"	"	3300
"	F	1.70	"	"	3900	"	"	3900
54	B	1.20	"	"	3350	"	"	3350
"	D	1.54	"	"	4110	"	"	4110
"	F	1.90	"	"	5100	"	"	5100
60	B	1.30	"	"	4000	"	"	4000
"	D	1.70	"	"	5000	"	"	5000
"	F	2.10	"	"	6200	"	"	6200

Table No. 7

Branches



Dimensions in Inches									Weight			
Nom. Diam	f	l	s	p	x	y	g	Class	3 way Branch		4 way Branch	
									2 bells	3 bells	3 bells	4 bells
4	4	11	23	11				K	125	130	155	160
6	"	12	24	12				I	170	170	205	205
"	6	"	"	"				"	190	190	240	240
8	4	13	25	13				"	250	240	285	275
"	6	"	"	"				"	275	260	325	310
"	8	"	"	"				"	290	280	370	360
10	4	14	26	14				H	340	325	375	360
"	6	"	"	"				"	360	340	410	390
"	8	"	"	"				"	380	360	450	435
"	10	"	"	"				"	405	390	505	490
12	4	15	27	15				"	450	425	490	460
"	6	"	"	"				"	470	440	510	485
"	8	"	"	"				"	485	460	555.	530
"	10	"	"	"				"	510	490	605	575
"	12	"	"	"	1.25	1.62	2.50	"	570	540	710	680
14	4	16	28	16				"	570	540	610	580
"	6	"	"	"				"	590	560	635	605
"	8	"	"	"				"	610	580	675	645
"	10	"	"	"				"	630	600	720	690
"	12	"	"	"	"	"	"	"	685	655	825	795
"	14	"	"	"	"	"	"	"	715	685	895	860
16	4	17	29	17				"	735	705	770	740
"	6	"	"	"				"	750	715	790	760
"	8	"	"	"				"	765	735	830	800
"	10	"	"	"				"	790	760	875	845
"	12	"	"	"	"	"	"	"	835	805	975	945
"	14	"	"	"	"	"	"	"	865	835	1040	1010
"	16	"	"	"	"	"	"	"	935	905	1170	1140
18	4	18	30	18				D	725	730	760	760
"	"	"	"	"				F	810	795	845	825
"	6	"	"	"				D	745	745	790	790
"	"	"	"	"				F	830	810	875	860
"	8	"	"	"				D	765	765	830	830

Table No. 7
(continued)

Branches

Dimensions in Inches									Weight			
Nom. Diam.	f	l	s	p	x	y	g	Class	3 way Branch		4 way Branch	
									2 bells	3 bells	3 bells	4 bells
18	8	18	30	18				F	850	830	915	895
"	10	"	"	"				D	785	785	875	880
"	"	"	"	"				F	870	850	955	940
"	12	"	"	"	1.25	1.62	2.50	D	845	845	990	990
"	"	"	"	"	"	"	"	F	925	905	1070	1050
"	14	"	"	"	"	"	"	D	875	875	1050	1060
"	"	"	"	"	"	"	"	F	955	935	1130	1110
"	16	"	"	"	"	"	"	D	945	945	1200	1200
"	"	"	"	"	"	"	"	F	1020	1010	1260	1250
"	18	"	"	"	"	"	"	D	945	945	1200	1200
"	"	"	"	"	"	"	"	F	1040	1030	1310	1290
20	6	19	31	19				D	895	895	935	935
"	"	"	"	"				F	1010	990	1055	1030
"	8	"	"	"				D	905	905	975	975
"	"	"	"	"				F	1030	1010	1090	1070
"	10	"	"	"				D	935	935	1020	1020
"	"	"	"	"				F	1050	1025	1135	1110
"	12	"	"	"	"	"	"	D	975	975	1110	1110
"	"	"	"	"	"	"	"	F	1090	1070	1220	1200
"	14	"	"	"	"	"	"	D	1005	1005	1170	1170
"	"	"	"	"	"	"	"	F	1120	1100	1280	1255
"	16	"	"	"	"	"	"	D	1055	1055	1260	1260
"	"	"	"	"	"	"	"	F	1185	1160	1400	1375
"	18	"	"	"	"	"	"	D	1080	1090	1330	1330
"	"	"	"	"	"	"	"	F	1220	1190	1470	1450
"	20	"	"	"	"	"	"	D	1125	1125	1400	1400
"	"	"	"	"	"	"	"	F	1260	1235	1560	1535
24	6	21	33	21				D	1240	1230	1280	1270
"	"	"	"	"				F	1410	1370	1460	1420
"	8	"	"	"				D	1250	1240	1310	1300
"	"	"	"	"				F	1430	1390	1490	1450
"	10	"	"	"				D	1280	1270	1360	1360
"	"	"	"	"				F	1450	1410	1520	1490
"	12	"	"	"	"	"	"	D	1320	1310	1450	1450
"	"	"	"	"	"	"	"	F	1490	1450	1610	1580
"	14	"	"	"	"	"	"	D	1350	1340	1510	1500
"	"	"	"	"	"	"	"	F	1510	1470	1660	1630
"	16	"	"	"	"	"	"	D	1410	1400	1630	1620
"	"	"	"	"	"	"	"	F	1570	1530	1780	1740
"	18	"	"	"	"	"	"	D	1420	1410	1650	1640
"	"	"	"	"	"	"	"	F	1600	1550	1830	1790
"	20	"	"	"	"	"	"	D	1460	1450	1720	1710
"	"	"	"	"	"	"	"	F	1650	1610	1920	1880

Table No. 7
(continued)

Branches

Dimensions in Inches									Weight			
									3 way Branch		4 way Branch	
Nom. Diam.	f	l	s	p	x	y	g	Class	2 bells	3 bells	3 bells	4 bells
24	24	21	33	21	1.25	1.62	2.50	D	1530	1520	1870	1860
"	"	"	"	"	"	"	"	F	1730	1690	2090	2040
30	12	15	27	24	"	"	"	B	1280	1310	1400	1440
"	"	"	"	"	"	"	"	D	1500	1480	1630	1610
"	"	"	"	"	"	"	"	F	1710	1630	1830	1750
"	14	16	28	"	"	"	"	B	1350	1380	1490	1530
"	"	"	"	"	"	"	"	D	1580	1560	1740	1710
"	"	"	"	"	"	"	"	F	1790	1720	1930	1860
"	16	17	29	"	"	"	"	B	1450	1480	1640	1680
"	"	"	"	"	"	"	"	D	1690	1670	1890	1870
"	"	"	"	"	"	"	"	F	1910	1830	2100	2020
"	18	18	32	"	"	"	"	B	1530	1520	1750	1740
"	"	"	"	"	"	"	"	D	1790	1720	2010	1940
"	"	"	"	"	"	"	"	F	2060	1920	2280	2140
"	20	19	34	"	"	"	"	B	1630	1610	1870	1850
"	"	"	"	"	"	"	"	D	1910	1820	2150	2060
"	"	"	"	"	"	"	"	F	2180	2020	2440	2280
"	24	21	36	"	"	"	"	B	1770	1750	2070	2050
"	"	"	"	"	"	"	"	D	2080	1980	2390	2290
"	"	"	"	"	"	"	"	F	2380	2220	2700	2540
"	30	24	41	"	1.50	2.00	3.00	B	2070	2010	2510	2450
"	"	"	"	"	"	"	"	D	2430	2280	2890	2750
"	"	"	"	"	"	"	"	F	2780	2560	3240	3010
36	12	15	27	27	1.25	1.62	2.50	B	1650	1700	1760	1800
"	"	"	"	"	"	"	"	D	1960	1920	2070	2030
"	"	"	"	"	"	"	"	F	2270	2150	2370	2260
"	14	16	28	"	"	"	"	B	1730	1770	1870	1910
"	"	"	"	"	"	"	"	D	2050	2010	2190	2150
"	"	"	"	"	"	"	"	F	2370	2260	2500	2390
"	16	17	29	"	"	"	"	B	1840	1880	2020	2060
"	"	"	"	"	"	"	"	D	2170	2130	2360	2320
"	"	"	"	"	"	"	"	F	2510	2400	2680	2570
"	18	18	32	"	"	"	"	B	1940	1930	2150	2140
"	"	"	"	"	"	"	"	D	2310	2200	2520	2410
"	"	"	"	"	"	"	"	F	2690	2500	2900	2690
"	20	19	34	"	"	"	"	B	2070	2030	2290	2250
"	"	"	"	"	"	"	"	D	2450	2310	2670	2530
"	"	"	"	"	"	"	"	F	2860	2620	3090	2850
"	24	21	36	"	"	"	"	B	2230	2190	2500	2470
"	"	"	"	"	"	"	"	D	2640	2500	2920	2780
"	"	"	"	"	"	"	"	F	3080	2840	3370	3130
"	30	24	41	"	1.50	2.00	3.00	B	2570	2470	2970	2870
"	"	"	"	"	"	"	"	D	3040	2830	3450	3240

Table No. 7 (continued)

Branches

Dimensions in Inches									Weight			
									3 way Branch		4 way Branch	
Nom. Diam.	f	l	s	p	x	y	g	Class	2 bells	3 bells	3 bells	4 bells
36	30	24	41	27	1.50	2.00	3.00	F	3550	3220	3940	3720
"	36	27	44	"	"	"	"	B	2860	2770	3390	3290
"	"	"	"	"	"	"	"	D	3390	3180	3940	3730
"	"	"	"	"	"	"	"	F	3970	3630	4550	4210
42	12	15	27	30	1.25	1.62	2.50	B	2110	2170	2220	2280
"	"	"	"	"	"	"	"	D	2520	2470	2630	2580
"	"	"	"	"	"	"	"	F	2920	2780	3020	2880
"	14	16	28	"	"	"	"	B	2200	2260	2330	2390
"	"	"	"	"	"	"	"	D	2630	2580	2760	2710
"	"	"	"	"	"	"	"	F	3050	2910	3160	3020
"	16	17	29	"	"	"	"	B	2330	2390	2510	2570
"	"	"	"	"	"	"	"	D	2780	2730	2960	2910
"	"	"	"	"	"	"	"	F	3200	3060	3370	3230
"	18	18	32	"	"	"	"	B	2450	2450	2650	2650
"	"	"	"	"	"	"	"	D	2940	2810	3140	3000
"	"	"	"	"	"	"	"	F	3430	3160	3620	3350
"	20	19	34	"	"	"	"	B	2600	2570	2820	2780
"	"	"	"	"	"	"	"	D	3120	2940	3330	3150
"	"	"	"	"	"	"	"	F	3630	3320	3840	3530
"	24	21	36	"	"	"	"	B	2800	2760	3050	3010
"	"	"	"	"	"	"	"	D	3350	3170	3600	3420
"	"	"	"	"	"	"	"	F	3900	3590	4150	3840
"	30	24	41	"	1.50	2.00	3.00	B	3180	3070	3540	3430
"	"	"	"	"	"	"	"	D	3820	3550	4180	3910
"	"	"	"	"	"	"	"	F	4460	4030	4840	4410
"	36	27	44	"	"	"	"	B	3510	3400	3980	3870
"	"	"	"	"	"	"	"	D	4210	3950	4700	4430
"	"	"	"	"	"	"	"	F	4900	4480	5400	4970
"	42	30	47	"	"	"	"	B	3930	3810	4610	4490
"	"	"	"	"	"	"	"	D	4700	4430	5420	5140
"	"	"	"	"	"	"	"	F	5480	5050	6200	5780
48	16	17	29	33	1.25	1.62	2.50	B	2850	2920	3040	3100
"	"	"	"	"	"	"	"	D	3420	3350	3600	3530
"	"	"	"	"	"	"	"	F	4000	3790	4150	3940
"	18	18	32	"	"	"	"	B	3020	3000	3210	3190
"	"	"	"	"	"	"	"	D	3640	3450	3820	3640
"	"	"	"	"	"	"	"	F	4260	3910	4440	4090
"	20	19	34	"	"	"	"	B	3180	3120	3390	3320
"	"	"	"	"	"	"	"	D	3840	3600	4040	3800
"	"	"	"	"	"	"	"	F	4520	4100	4710	4300
"	24	21	36	"	"	"	"	B	3400	3340	3650	3590
"	"	"	"	"	"	"	"	D	4110	3870	4350	4110
"	"	"	"	"	"	"	"	F	4830	4420	5060	4650

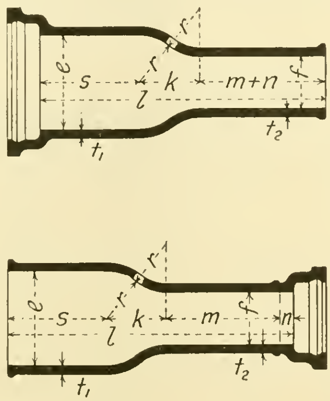
Table No. 7
(concluded)

Branches

Dimensions in Inches									Weight			
Nom. Diam.	f	l	s	p	x	y	g	Class	3 way Branch		4 way Branch	
									2 bells	3 bells	3 bells	4 bells
48	30	24	41	33	1.50	2.00	3.00	B	3850	3700	4200	4050
"	"	"	"	"	"	"	"	D	4650	4300	5000	4650
"	"	"	"	"	"	"	"	F	5480	4930	5810	5250
"	36	27	44	"	"	"	"	B	4210	4060	4640	4490
"	"	"	"	"	"	"	"	D	5100	4750	5510	5160
"	"	"	"	"	"	"	"	F	6000	5440	6410	5850
"	42	30	48	"	"	"	"	B	4720	4520	5310	5120
"	"	"	"	"	"	"	"	D	5680	5280	6300	5900
"	"	"	"	"	"	"	"	F	6670	6040	7280	6650
"	48	33	50	"	"	"	"	B	5100	4950	5870	5720
"	"	"	"	"	"	"	"	D	6150	5800	6950	6600
"	"	"	"	"	"	"	"	F	7220	6670	8050	7490

Table No. 11

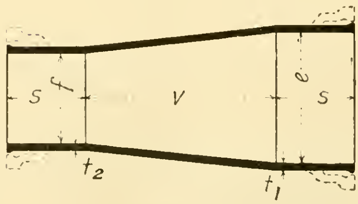
Reducers.–Type I



Dimensions in Inches											Weight	
Nom. diam		s	k	m	n	l	r	t_1	t_2	Class	Bell on Large end	Bell on Small end
e	f											
6	4	10	3.3	14.7	2	30	3	.54	.48	I	100	90
8	"	"	5.3	12.7	"	"	4	.63	"	"	135	110
"	6	"	3.9	14.1	"	"	"	"	.54	"	150	140
10	4	"	7.1	10.9	"	"	5	.70	.48	H	175	140
"	6	"	6.0	12.0	"	"	"	"	.54	"	190	165
"	8	"	4.4	13.6	"	"	"	"	.63	"	215	200
12	6	"	7.9	10.1	"	"	6	77	.54	"	235	195
"	8	"	6.6	11.4	"	"	"	"	.63	"	255	230
"	10	"	4.8	13.2	"	"	"	"	.70	"	285	270

Table No. 12

Reducers – Type 2



Dimensions in Inches							Weight		
Nom. Diam. e	Nom. Diam. f	v	s	t_1	t_2	Class	Spigot ends	Bell on Large end	Bell on Small end
14	6	20	8	83	.54	H	230	275	250
"	8	"	"	"	.63	"	260	305	285
"	10	"	"	"	.70	"	290	335	320
"	12	"	"	"	.77	"	330	370	365
16	6	"	"	90	.54	"	270	330	290
"	8	"	"	"	63	"	300	360	330
"	10	"	"	"	.70	"	335	390	365
"	12	"	"	"	.77	"	370	425	405
"	14	"	"	"	.83	"	410	465	450
18	8	"	"	75	63	D	285	370	315
"	"	"	"	.86	"	F	315	390	340
"	10	"	"	.75	.70	D	320	400	350
"	"	"	"	.86	"	F	350	420	380
"	12	"	"	.75	.75	D	355	435	390
"	"	"	"	.86	.77	F	385	460	420
"	14	"	"	.75	.75	D	375	455	420
"	"	"	"	.86	.83	F	425	500	465
"	16	"	"	.75	.75	D	395	480	465
"	"	"	"	.86	.86	F	460	535	520
20	10	26	"	.79	.70	D	410	505	440
"	"	"	"	.92	"	F	455	545	485
"	12	"	"	.79	77	D	455	550	490
"	"	"	"	.92	"	F	500	585	535
"	14	"	"	.79	79	D	490	580	530
"	"	"	"	.92	83	F	545	630	590
"	16	"	"	.79	.79	D	515	610	580
"	"	"	"	.92	90	F	595	685	655
"	18	"	"	.79	75	D	530	625	610
"	"	"	"	.92	.86	F	615	700	690
24	14	"	"	.88	.83	D	590	710	635
"	"	"	"	1.03	"	F	650	760	695
"	16	"	"	.88	.88	D	640	755	695
"	"	"	"	1.03	.90	F	705	815	765
"	18	"	"	.88	.75	D	620	740	700
"	"	"	"	1.03	.86	F	725	830	800
"	20	"	"	.88	.79	D	665	785	760
"	"	"	"	1.03	.92	F	780	885	865
30	18	"	"	81	.75	B	675	855	755

Table No. 12
(continued)

Reducers.–Type 2

Dimensions in Inches							Weight		
Nom. Diam. e	Nom. Diam. f	V	S	t_1	t_2	Class	Spigot ends	Bell on Large end	Bell on Small end
30	18	26	8	1.01	75	D	775	930	855
"	"	"	"	1.20	.86	F	910	1050	985
"	20	"	"	.81	.79	B	715	895	810
"	"	"	"	1.01	"	D	820	975	910
"	"	"	"	1.20	.92	F	970	1110	1100
"	24	"	"	.81	.81	B	780	960	910
"	"	"	"	1.01	.88	D	920	1080	1040
"	"	"	"	1.20	1.03	F	1090	1230	1200
36	20	32	"	.90	.79	B	975	1210	1070
	"	"	"	1.13	"	D	1130	1330	1220
"	"	"	"	1.37	.92	F	1360	1530	1450
"	24	"	"	.90	.88	B	1090	1320	1210
"	"	"	"	1.13	"	D	1250	1450	1370
"	"	"	"	1.37	1.03	F	1500	1670	1610
"	30	"	"	.90	.81	B	1150	1380	1330
"	"	"	"	1.13	1.01	D	1440	1640	1600
"	"	"	"	1.37	1.20	F	1740	1910	1880
42	20	"	"	1.00	.79	B	1150	1460	1250
"	"	"	"	1.27	"	D	1360	1630	1460
"	"	"	"	1.53	.92	F	1640	1860	1720
"	24	"	"	1.00	.88	B	1270	1580	1390
"	"	"	"	1.27	"	D	1490	1750	1600
"	"	"	"	1.53	1.03	F	1790	2010	1890
"	30	"	"	1.00	.81	B	1330	1640	1510
"	"	"	"	1.27	1.01	D	1690	1950	1850
"	"	"	"	1.53	1.20	F	2040	2260	2170
"	"	66	"	1.00	.81	B	2270	2580	2450
"	"	"	"	1.27	1.01	D	2870	3140	3030
"	"	"	"	1.53	1.20	F	3470	3690	3600
"	36	32	"	1.00	.90	B	1500	1810	1740
"	"	"	"	1.27	1.13	D	1910	2180	2110
"	"	"	"	1.53	1.37	F	2320	2540	2490
"	"	66	"	1.00	.90	B	2560	2870	2790
"	"	"	"	1.27	1.13	D	3250	3520	3460
"	"	"	"	1.53	1.37	F	3950	4180	4120
48	30	32	"	1.10	.81	B	1540	1920	1720
"	"	"	"	1.40	1.01	D	1950	2280	2110
"	"	"	"	1.70	1.20	F	2360	2630	2500
"	"	132	"	1.10	.81	B	4700	5090	4890
"	"	"	"	1.40	1.01	D	5970	6290	6130
"	"	"	"	1.70	1.20	F	7230	7500	7360
"	36	32	"	1.10	.90	B	1710	2090	1940
"	"	"	"	1.40	1.13	D	2180	2500	2390
"	"	"	"	1.70	1.37	F	2650	2920	2820

Table No. 12
(continued)

Reducers.–Type 2

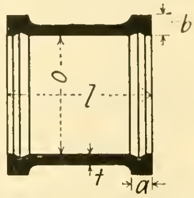
Dimensions in Inches							Weight		
Nom. Diam. e	Nom. Diam. f	V	S	t_1	t_2	Class	Spigot ends	Bell on Large end	Bell on Small end
48	36	132	8	1.10	.90	B	5250	5630	5480
"	"	"	"	1.40	1.13	D	6700	7020	6900
"		"	"	1.70	1.37	F	8140	8410	8310
"	42	32	"	1.10	1.00	B	1910	2290	2220
"	"	"	"	1.40	1.27	D	2440	2770	2710
"	"	"	"	1.70	1.53	F	2970	3240	3200
"	"	132	"	1.10	1.00	B	5880	6260	6190
"	"	"	"	1.40	1.27	D	7510	7840	7780
"	"	"	"	1.70	1.53	F	9140	9410	9370
54	36	66	"	1.20	.90	B	3300	3790	3530
"	"	"	"	1.54	1.13	D	4220	4630	4430
"	"	"	"	1.90	1.37	F	5200	5720	5370
"	"	132	"	1.20	.90	B	5940	6430	6170
"	"	"	"	1.54	1.13	D	7600	8010	7810
"	"	"	"	1.90	1.37	F	9360	9880	9530
"	42	66	"	1.20	1.00	B	3650	4140	3960
"	"	"	"	1.54	1.27	D	4690	5100	4960
"	"	"	"	1.90	1.53	F	5770	6290	6000
"	"	132	"	1.20	1.00	B	6580	7070	6890
"	"	"	"	1.54	1.27	D	8450	8860	8720
"	"	"	"	1.90	1.53	F	10400	10900	10600
"	48	66	"	1.20	1.10	B	4040	4530	4420
"	"	"	"	1.54	1.40	D	5200	5610	5520
"	"	"	"	1.90	1.70	F	6400	6910	6670
"	"	132	"	1.20	1.10	B	7290	7780	7670
"	"	"	"	1.54	1.40	D	9370	9780	9700
"	"	"	"	1.90	1.70	F	11550	12050	11800
60	36	66	"	1.30	.90	B	3710	4280	3940
"	"	"	"	1.70	1.13	D	4810	5280	5010
"	"	"	"	2.10	1.37	F	5940	6520	6110
"	"	132	"	1.30	.90	B	6670	7240	6900
"	"	"	"	1.70	1.13	D	8650	9120	8850
"	"	"	"	2.10	1.37	F	10680	11260	10850
"	42	66	"	1.30	1.00	B	4080	4650	4390
"	"	"	"	1.70	1.27	D	5310	5770	5570
"	"	"	"	2.10	1.53	F	6540	7110	6760
"	"	132	"	1.30	1.00	B	7340	7910	7650
"	"	'	"	1.70	1.27	D	9550	10000	9820
"	"	"	"	2.10	1.53	F	11800	12350	12000
"	48	66	"	1.30	1.10	B	4480	5040	4860
"	"	"	"	1.70	1.40	D	5820	6290	6150
"	"	"	"	2.10	1.70	F	7180	7760	7450
"	"	132	"	1.30	1.10	B	8070	8630	8450
"	"	"	"	1.70	1.40	D	10500	10950	10800

Table No. 12
(concluded)

Reducers.–Type 2

Dimensions in Inches							Weight		
Nom Diam. e	Nom Diam. f	v	s	t_1	t_2	Class	Spigot ends	Bell on Large end	Bell on Small end
60	48	132	8	2.10	1.70	F	12950	13500	13200
"	54	66	"	1.30	1.20	B	4900	5470	5390
"	"	"	"	1.70	1.54	D	6400	6860	6810
"	"	"	"	2.10	1.90	F	7940	8520	8460
"	"	132	"	1.30	1.20	B	8840	9400	9330
"	"	"	"	1.70	1.54	D	11550	12000	11950
"	"	"	"	2.10	1.90	F	14300	14900	14850

Table No 13



Sleeves

Dimensions in Inches							Weight
Nom. Diam.	Class	a	b	l	o	t	
4	K	1.50	1.30	10	5.8	.65	45
6	I	"	1.40	"	7.9	.70	65
8	"	"	1.50	12	10.1	.75	100
10	H	"	"	"	12.2	"	120
12	"	"	1.60	14	14.3	.80	170
14	"	"	1.70	15	16.4	.85	220
16	"	1.75	1.80	"	18.7	.90	275
18	D	"	1.90	"	20.5	.95	315
"	F	"	"	"	20.8	"	320
20	D	"	2.00	"	22.6	1.00	365
"	F	"	"	"	23.1	"	375
24	D	2.00	2.10	"	26.7	1.05	465
"	F	"	"	"	27.2	"	475
30	B	"	2.30	"	32.7	1.15	620
"	D	"	"	"	33.1	"	630
"	F	"	"	"	33.5	"	635
36	B	"	2.50	"	38.9	1.25	805
"	"	"	"	20	"	"	1010
"	D	"	"	15	39.4	"	815
"	"	"	"	20	"	"	1020
"	F	"	"	15	39.8	"	820
"	"	"	"	20	"	"	1030
42	B	"	2.80	15	45.1	1.40	1050
"	"	"	"	20	"	"	1310
"	D	"	"	15	45.6	"	1060
"	"	"	"	20	"	"	1330
"	F	"	"	15	46.2	"	1070
"	"	"	"	20	"	"	1340
48	B	"	3.00	15	51.3	1.50	1280
"	"	"	"	20	"	"	1600
"	D	"	"	15	51.9	"	1290
"	"	"	"	20	"	"	1620
"	F	"	"	15	52.5	"	1300
"	"	"	"	20	"	"	1640
54	B	2.25	3.20	15	57.5	1.60	1570
"	"	"	"	20	"	"	1960
"	D	"	"	15	58.2	"	1590
"	"	"	"	20	"	"	1980
"	F	"	3.80	15	58.9	1.90	1940
"	"	"	"	20	"	"	2410
60	B	"	3.40	15	63.7	1.70	1850
"	"	"	"	20	"	"	2300
"	D	"	"	15	64.5	"	1870
"	"	"	"	20	"	"	2330
"	F	"	4.00	15	65.3	2.00	2260
"	"	"	"	20	"	"	2810

APPENDIX.

Report of the Foundry Committee.

January 31, 1902.

Freeman C. Coffin, F. F. Forbes, Dexter Brackett, Committee on Standard Specifications for Cast-Iron Pipe, of the New England Water Works Association:

Gentlemen, — The Committee appointed by the Cast-Iron Pipe Founders desire to acknowledge the care and thoroughness with which the subject of standard specifications has been taken in hand by yourselves. In considering the papers submitted, they have viewed them, first, from the standpoint of securing good castings and such as will commend themselves to the general average of the trade, and doing this with the thought of not increasing unduly the cost of manufacturing the pipe, which cost must be in the end borne by the purchaser. They desire you to appreciate that the changes they suggest have in many instances arisen from their intimate knowledge of the business, both from the standpoint of manufacturers and also from the market requirements. They feel the reasons which have prompted them to the changes which have been made had best be discussed by a joint meeting of your Committee and the committee of the Cast-Iron Pipe Founders.

It may be well to give the reasons for departing from the suggestion of a uniform external diameter of pipe. Roughly, they are that adhering to uniform external diameters will tend to increase the cost of manufacturing, and also produce bad pipe. As to the schedule of and variation of weights, the changes in the variation of weight have been made so as to permit of cheapening production, without increasing the cost of the pipe to the buyer. It is to fully explain these and other changes that the pipe manufacturers would be glad to have a meeting with your committee.

SPECIFICATIONS

Suggested by the Foundry Committee.

DESCRIPTION OF PIPES.

The pipes shall be made with hub and spigot joints, which shall accurately conform to the dimensions given in Table No. 1. The nominal diameter shall be the actual diameter.

They shall be true circles in sections, with their inner and outer surfaces concentric.

The straight pipes shall be straight, and the curved pipes shall be true to the required curvature in the direction of their axis.

They shall be of the specified dimensions in internal diameter from end to end, and the straight pipe shall be at least twelve feet in length, exclusive of socket.

Especial care shall be taken to have the sockets of the required size. The sockets and spigots will be tested by circular gages, and no pipe will be received which is defective in joint room from any cause. The joint room for each class of pipe shall not vary more than .06 of an inch from the dimensions given in Table No. 1.

Pipes 16 inches or less in diameter shall be accepted when the thickness of metal in the body of the pipe is not more than .08 of an inch less at any point than the standard thickness, but for pipes over 16 inches in diameter, the variation may be .12 of an inch.

The length of the pipe shall not be changed except by written permission of the engineer, and in case of such change the standard weight of the pipe shall be modified in accordance therewith.

DEFECTIVE SPIGOTS.

Defective spigot ends on pipes may be cut off in a lathe, and a half-round wrought-iron band shrunk into a groove cut in the end of the pipe. No pipe shall be banded which is less than eleven feet in length, exclusive of the socket. That portion of the spigot end of a pipe or special casting which enters the bell shall not be picked or hammered by the inspector.

SPECIAL CASTINGS.

All special castings shall be made in accordance with the cuts and the dimensions given in the tables forming a part of these specifications.

The flanges on all manhole castings and manhole covers shall be faced true and smooth, and drilled to receive bolts of the sizes given in the tables. The contractor shall furnish and deliver all bolts for bolting on the manhole covers, the bolts to be of the sizes shown on the plans, with hexagonal heads and nuts, and sound, well-fitting threads.

MARKING.

Every pipe and special casting shall have distinctly cast upon it the initials of the maker's name, the year in which it was cast, and the class letter. When cast especially to order, each pipe and special casting shall also have cast upon it the number signifying the order in point of time in which it was cast, the figures denoting the year being above and the number below, thus, —

1901	1901	1901
1	2	3

etc., also any initials, not exceeding four, which may be required by the purchaser.

The letters and figures are to be cast on the outside, not less than two inches in length and one-eighth of an inch in relief, on pipe eight inches and over; on smaller pipe size of letters to be proportionate.

PERCENTAGE TO BE PAID FOR.

No pipe shall be accepted the weight of which shall be less than the standard weight by more than five per cent. for pipes sixteen inches or less in diameter, and four per cent. for pipes more than sixteen inches in diameter; and no excess above the standard weight of more than the given percentage for the several sizes shall be paid for. The total weight to be paid for shall not exceed for each size and class of pipe the sum of the standard weights for the same number of pieces of the given size and class by more than two per cent.

No special casting shall be accepted the weight of which is more than twelve per cent. less than the standard weight, and not more than twelve per cent. in excess of the standard weight shall be paid for.

QUALITY OF IRON.

The metal shall be made without any admixture of cinder iron or other inferior metal, and shall be remelted in a cupola or air furnace. It shall be of such character as to make a pipe strong, tough, and of

even grain, and soft enough to satisfactorily admit of drilling and cutting.

Specimen bars of the metal used, each being 26 inches long by 2 inches wide and 1 inch thick, shall be made without charge as often as the engineer may direct. The bars, when placed flatwise upon supports 24 inches apart and loaded in the center, shall support a load of 1 800 pounds, and show a deflection of not less than .30 of an inch before breaking. Should the dimensions of the bars differ from those above given, a proper allowance therefor shall be made in the results of the tests. The founder shall have the right to pour three bars from each ladle, and the decision of the test shall be based on the average result.

HOW CAST.

The straight pipes shall be cast in dry sand molds, in a vertical position, and the pipe shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal contraction by subsequent exposure.

QUALITY OF CASTINGS.

The pipes and castings shall be smooth, free from scales, lumps, blisters, sand holes, and defects of every nature which unfit them for the use for which they are intended. No plugging or filling will be allowed.

CLEANING AND INSPECTION.

All pipes and special castings shall be thoroughly cleaned and subjected to a careful hammer inspection, but no pick shall be used. No casting shall be coated unless entirely clean and free from rust, and approved in these respects by the engineer immediately before being dipped.

COATING.

Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle, nor with any tendency to scale off.

Each casting shall be heated to a temperature of 300 degrees Fahrenheit immediately before it is dipped, and shall possess not

less than this temperature at the time it is put in the vat. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

The varnish shall be heated to a temperature of 300 degrees Fahrenheit (or less if the engineer shall so order) and shall be maintained at this temperature during the time the casting is immersed.

Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated, the pipes shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be recoated shall first be thoroughly scraped and cleaned.

HYDROSTATIC TEST.

When the coating has become hard, the straight pipes shall be subjected to a proof by hydrostatic pressure, and, if required by the engineer, they shall also be subjected to a hammer test under this pressure.

The pressure to which the different sizes and classes of pipes shall be subjected is, for

Class A,	200	pounds	per	square	inch.
,, B,	250	,,	,,	,,	,,
,, C,	300	,,	,,	,,	,,
,, D.	300	,,	,,	,,	,,

WEIGHING.

The pipes and special castings shall be weighed for payment under the supervision of the engineer, after the application of the coal-tar pitch varnish, and the weight of each pipe and special casting shall be conspicuously painted in white on the inside, after the coating has become hard. If desired by the engineer, the pipes and special castings shall be weighed after their delivery, and the weights so ascertained shall be used in the final settlement, provided such weighing is done by legalized weighmaster.

CONTRACTOR TO FURNISH MEN AND MATERIALS.

The contractor shall provide all tools, materials, and men necessary for the proper testing, inspection, and weighing at the foundry of the

pipes and special castings; should the buyer have no inspector at the works the founders shall, if notified by the engineer, furnish a sworn statement that all of the tests have been made as specified, this statement to contain the results of the transverse tests upon the test bars.

POWER OF THE ENGINEER TO INSPECT.

The engineer shall be at liberty at all times to inspect the material at the foundry, and the moulding, casting, and coating of the pipes and special castings. The forms, sizes, uniformity, and conditions of all pipes and other castings herein referred to shall be subject to his inspection and approval, and he may reject, without proving, any pipe or other casting which is not in conformity with the specifications or drawings furnished.

CASTINGS TO BE DELIVERED SOUND AND PERFECT.

All the pipes and other castings must be delivered in all respects sound and conformable to these specifications. The inspection shall not relieve the contractor of any of his obligations in this respect, and any defective pipe or other casting which may have passed the engineer at the works or elsewhere shall be at all times liable to rejection when discovered, until the final completion and adjustment of the contract. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material of any kind shall be placed in the pipes during the transportation or at any time after they receive the coating.

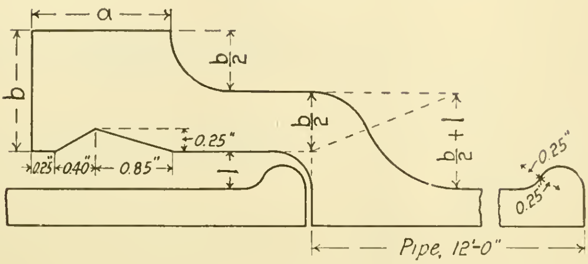
DEFINITION OF THE WORD "ENGINEER."

Wherever the word "engineer" is used herein it shall be understood to refer to the engineer, or inspector, acting for the purchaser, and to his properly authorized agents, limited by the particular duties intrusted to them, and all such instructions by any agents must be stated in writing in order to be binding.

INSPECTORS.

All inspectors must be experienced and fully competent for the work to which they are assigned.

TABLE NO. 1.—GENERAL DIMENSIONS OF PIPES AND SPECIAL CASTINGS.



Diam. Inches.	Depth of Sockets.		Thickness of Joint for Calking. Inches.	"a."	"b."
	Pipe. Inches.	Special Castings. Inches.			
4	3.00	4.00	.40	1.50	1.30
6	"	"	"	"	1.40
8	3.50	"	"	"	1.50
10	"	4.50	"	"	"
12	"	"	"	"	1.60
14	"	"	"	"	1.70
16	4.00	5.00	.50	1.75	1.80
18	"	"	"	"	1.90
20	"	"	"	"	2.00
24	"	"	"	2.00	2.10
30	4.50	"	"	"	2.30
36	"	"	"	"	2.50
42	5.00	"	"	"	2.80
48	"	"	"	"	3.00

TABLE NO. 2.—STANDARD WEIGHTS AND PRESSURES.

BELL AND SPIGOT CAST-IRON PIPE.

Inside Diameter of Pipe in Inches.	Approximate Laying Length in Feet.	CLASS A. HEAD, 100 FEET. PRESSURE, 43 POUNDS.			CLASS B. HEAD, 200 FEET. PRESSURE, 86 POUNDS.			CLASS C. HEAD, 300 FEET. PRESSURE, 130 POUNDS.			CLASS D. HEAD, 400 FEET. PRESSURE, 173 POUNDS.		
		Thickness.	Weight per Foot.	Weight per Length.	Thickness.	Weight per Foot.	Weight per Length.	Thickness.	Weight per Foot.	Weight per Length.	Thickness.	Weight per Foot.	Weight per Length.
4	12	.38	18.3	220	.42	20.3	243	.45	21.7	260	.47	22.9	275
6	12	.41	28.3	340	.47	32.8	393	.51	35.5	426	.54	37.1	445
8	12	.47	42.8	513	.51	47.3	567	.56	52.0	624	.61	55.4	665
10	12	.50	57.1	685	.56	63.8	765	.62	71.0	852	.68	76.7	920
12	12	.53	72.5	870	.60	82.1	985	.68	92.5	1 110	.75	100.8	1 210
14	12	.56	89.5	1 074	.65	102.4	1 229	.73	116.6	1 399	.82	128.3	1 540
16	12	.60	107.8	1 293	.69	124.7	1 496	.79	143.6	1 723	.89	158.3	1 900
18	12	.63	127.7	1 532	.74	149.0	1 788	.85	172.1	2 065	.96	191.7	2 300
20	12	.66	149.0	1 788	.78	175.3	2 104	.91	203.7	2 444	1.03	228.3	2 740
24	12	.75	200.6	2 407	.87	233.6	2 803	1.02	274.9	3 299	1.16	306.7	3 680
30	12	.87	290.2	3 482	1.01	335.6	4 027	1.19	398.6	4 783	1.37	451.7	5 420
36	12	.98	391.6	4 699	1.14	455.0	5 460	1.36	545.3	6 543	1.58	624.2	7 490
42	12	1.10	512.3	6 147	1.28	591.7	7 100	1.54	713.6	8 563	1.79	824.2	9 800
48	12	1.25	665.2	7 982	1.41	745.5	8 946	1.71	904.8	10 857	1.99	1 045.8	12 550

DISCUSSION.

Mr. Coffin. The specifications are printed here, and perhaps you will not see a very striking difference between them and the specifications which were submitted with the preliminary report. I do not know whether you will consider it desirable to have them read or not, as they are appended here, and also the specifications suggested by the foundry committee.

The President. Can you in a few words state what the changes are, without reading them through?

Mr. Coffin. I can state some of them, I think. I have already referred to abandoning of uniform outside diameters. The Committee, I may say, did their best to retain the original form; they went into the matter very carefully and became convinced it was not a practicable thing to do so. If it had been done, either the cost of the pipe would have been very greatly increased, or there would have been a possibility or a probability of getting a good many poor pipe. It required quite a difference in the thickness of the clay of the core to make all the difference between the thickest pipe and the thinnest pipe, and the manufacturers were unanimously of the opinion — and, after going into the matter thoroughly with them, we became convinced that they were sincere — that it could not be done to the extent that we called for in the original specifications. I believe that we have retained practically all of the benefits that would have been secured by our original proposition, because in the way they are designed it is possible to use the pipe from 4 to 16 inches interchangeably; that is, the lighter weights can be used with the heavier weights in a line, and *vice versa*, and one pattern of special castings can be used for all; and the Committee feel that they have done the best that they could do, everything considered.

There were several valuable suggestions made in the discussion of the preliminary report, and the Committee have adopted a number of them. I am afraid it is going to be rather hard for me to pick these out, but I will try to do so. In compliance with the request of the manufacturers' committee, referring to Section 2 of the Specifications, the allowable variation in the diameter of pipes and sockets was increased. Whereas in the original specifications, if my memory is right, the variation was .06 of an inch for all pipes, it now reads that the diameters "shall not vary . . . more than .06 of an inch for pipes 16 inches or less in diameter; .08 of an inch for 18-inch, 20-inch, and 24-inch pipes; .10 of an inch for 30-inch,

36-inch, and 42-inch pipes, and .12 of an inch for 48-inch, 54-inch, and 60-inch pipes." That varies more in accordance with the size of the pipe than the original specifications did.

The variation in thickness was increased somewhat. I don't remember what it was originally, but it now reads that "for pipes whose standard thickness is less than one inch, the thickness of metal in the body of the pipe shall not be more than .08 of an inch less than the standard thickness, and for pipes whose standard thickness is one inch or more the variation shall not exceed .10 of an inch, except that for spaces not exceeding 8 inches in length in any direction, variations from the standard thickness of .02 of an inch in excess of the allowances above given shall be permitted." That means that if there are thin spots on the pipe covering spaces which do not exceed 8 inches in either direction, the variation in thickness may be greater than it would be for long distances. Of course we all admit that when a pipe is tapped right through for services it does not materially weaken the pipe, at least we are quite ready to do it, and it seemed to the Committee it was quite safe to admit a little more variation on small spaces than on long lengths of pipe.

In regard to defective spigots which may be cut, the original specifications provided for cutting and banding a pipe 20 inches and under to an amount equal to 6 per cent. of the total number of pipes ordered. These specifications allow spigots to be cut on pipes 12 inches and over, the size has been reduced from 20 to 12 on not more than 12 per cent. of the total number; that is, we have doubled the total number which will be accepted.

In these variations from the original specifications to meet the request of the foundries, in some cases we met altogether what they required and in some cases we met them part way; but the members of the Committee considered the matter carefully and used their own judgment, and are now ready to recommend these specifications as they stand.

There has been a change made in regard to special castings. We allowed a little more variation in the diameters of the sockets of the special castings than we did in the pipes, recognizing the fact that special castings are made in a different way, and it is impossible to make them as close to the dimension in diameter as it is the pipe, some of them being made with cores and generally made with split patterns, etc. This is a matter of foundry detail which it seemed to the Committee did not go beyond the limits of good practice.

The change in marking is something which the Committee made of its own motion. Whereas in the original specifications the class letter was to be cast on the pipe, in these it is provided that the mark shall be painted on the inside, the same as the weight. The reason for doing this was that in casting pipe it is difficult to get the first pipe cast of the exact weight, and perhaps several have to be cast before the correct weight of the class can be found. If those overrun a class or underrun it, they can be marked into another class, and the Committee could see no objection to painting the class on the inside of the pipe as well as the weight. We have also allowed the sizes of the letters on pipes less than 8 inches in diameter to be 1 inch in length, whereas before it was provided that they should be 2 inches in length. That is a practical consideration; it is out of the question, perhaps, to cast a 2-inch letter on a pipe smaller than 8 inches.

"Percentage to be paid for," — there is a slight change in that. Whereas the former specification read: "No pipe shall be accepted the weight of which shall be less than the standard weight by more than 4 per cent. for pipes 16 inches or less in diameter, 3½ per cent. for 18-inch, 20-inch, and 24-inch pipes, and 3 per cent. for pipes more than 24 inches in diameter," — that is, the percentages were 4, 3½, and 3,— it now reads that this percentage of variation either above or below the standard weight shall be not "more than 5 per cent. for pipe 16 inches or less in diameter, and 4 per cent. for pipes more than 16 inches in diameter." The requirement as to the total weight for the whole order was not changed — that still remains at two per cent.; that is, the purchaser will not pay for more than two per cent. in excess. The variation in weights of special castings was raised from 6 to 10 per cent. The object of the Committee in meeting the manufacturers' committee on these points was to avoid extra expense where it seemed it would not produce a corresponding benefit.

"Tests of Material." The Committee reduced the requirement slightly for the transverse test. It reads now: "The bars, when placed flatwise upon supports 24 inches apart and loaded in the center, shall for pipes 12 inches or less in diameter support a load of 1 900 pounds and show a deflection of not less than .30 of an inch before breaking, and for pipes of sizes larger than 12 inches shall support a load of 2 000 pounds and show a deflection of not less than .32 of an inch." I believe the original specifications provided for a load of

2 000 pounds for all pipes, with a deflection of .35 of an inch. This was changed somewhat in deference to the conditions at foundries, which are perhaps a little outside of the foundries which would supply pipe for this market; that is, the Western and Southern foundries find it difficult, we are informed, to get iron which will make the proper mixture to reach the requirement we had originally made.

There is a little change in the casting of pipes. It reads now: "The straight pipes shall be cast in dry sand molds in a vertical position. Pipes 16 inches or less in diameter shall be cast with the hub end up or down, as specified in the proposal." Before it was to be as required by the engineer.

"Quality of Castings." The present specifications read: "The pipes and special castings shall be smooth, free from scales, lumps, blisters, sand holes, and defects of every nature which, in the opinion of the engineer, unfit them for the use for which they are intended." That last clause was inserted at the request of the foundries, — or, rather, their request was that it should read, "and defects of every nature which unfit them for the use for which they are intended," and the Committee inserted the words, "in the opinion of the engineer."

I believe those are about all the sections which were changed in deference to the manufacturers' committee. There was one section put in as follows: "The inspector at the foundry shall report daily to the foundry office all pipes and special castings rejected, with the causes for rejection." That seemed to be a reasonable requirement.

It is a little more difficult for me to remember the things which were put in on account of the discussion by members of the Association, for they are not so fresh in my mind. Here is one thing which was suggested in regard to the test of material: "In default of definite instructions the contractor shall make and test at least one bar from each heat or run of metal." And at the request of the manufacturers this clause was put in: "The contractor shall have the right to make and break three bars from each heat or run of metal, and the test shall be based upon the average results of the three bars."

There were some changes made in the hydrostatic test, but I really can't describe them now. And this clause was put in: "Bids shall be submitted and a final settlement made upon the basis of a ton of 2 000 pounds."

The Committee have also changed the form of the spigot ends and made a slight change in the form of the sockets, somewhat in accord-

ance with what was suggested in the discussion. By referring to the cut you will see that the bead on the spigot end is made somewhat heavier, and the socket meets the body of the pipe by a small fillet or extra thickness in the metal, shown on the cut by a dotted line. This is simply a practical detail of foundry work, as most pipe are cast that way, and the Committee thought it better to make the cut correspond with the practice. It was suggested that there should be a taper shown on the line of the socket marked "a." The Committee considered that it was the practice in all casting for the pattern-makers to make what is called a draft on the pattern, to allow the pattern to draw out of the sand, and that it was not necessary to show that on the cut. I presume that there are things which I have forgotten to state, but I have mentioned all which occur to me now.

The President. I consider this report one of the most important ever submitted to this Association, and I hope there will be a full and free discussion. The report is now before you, gentlemen, for your consideration.

Mr. Coffin. One more thing I would like to speak of, Mr. President, and that is, that the table of weights of pipe, Table No. 2, was changed by omitting every other class of the sizes from 4 to 8 inches, and carrying the classes a little further on in the case of those sizes, and also in the case of pipe up to 16 inches in diameter. The original table provided up to Class F, but now 4-inch pipe go to Class K, 6- and 8-inch to Class I, and 10-, 12-, 14-, and 16-inch to Class H. This was to provide for practice where they use heavier pipe than is customary in this vicinity.

The President. We shall be glad to hear from any one who is interested in this matter of standard specifications for cast-iron pipe.

Mr. Leonard Metcalf.* It seems to me that the Committee has presented such an excellent set of specifications that there is not much to criticise, and without opportunity for criticism it is very hard to get up a discussion. I agree very heartily with our President that the Committee have done a work of great value to our Association and to water-works men in general. I only hope that their work may extend a little further, and that they will give us also, as I believe they intend to do, a list of special castings which can be used in conjunction with these specifications.

Mr. Coffin. It is the intention of the Committee to prepare

* Civil Engineer, Boston, Mass.

such a list if the specifications are adopted. It will involve considerable labor and some expense, therefore the Committee concluded it was better not to undertake to do it until the matter of the specifications was finally settled.

Mr. Metcalf. I should like to ask Mr. Coffin if it is the idea of the Committee that it would be wiser to adopt these specifications now, or whether they think the matter had better be held open to await action on the part of any of the other associations, as, for instance, the American Water Works Association. I believe that organization is considering this matter, and I do not know but what the Committee has been in correspondence with its committee, although no allusion is made to that in the report.

Mr. Coffin. I do not know that I can answer that question for the Committee. We feel that we have done our work now, and we have presented these specifications to the Association for it to adopt or to take any action which it sees fit in regard to them. As I look at it, I think nothing would be gained by delay. I believe that if there were any important changes to be made in order to come to an agreement with other associations, perhaps they could be made afterwards as well; and I think it may be fair to say that no action will be taken by other associations until this Association takes action on these specifications. I would like, however, to hear from the other members of the Committee on this point, for I do not assume to speak for them upon this matter, as that is something which has not been discussed in the Committee.

Mr. Metcalf. In other words, you think that if this Association takes the initiative in this matter the other associations will fall into line.

Mr. Coffin. Yes, sir; and perhaps suggest some desirable amendments.

Mr. Charles W. Sherman. On that subject, Mr. President, it may be of interest for me to say that I was looking over the report of the last convention of the American Water Works Association no longer ago than last evening, and read there the action taken by their committee on cast-iron pipe specifications. The report of that committee consists principally of a statement that our Committee is doing valuable work in this direction and a reprint of the preliminary specifications prepared by our Committee last winter, with the suggestion that those specifications, or revised specifications, would come up for final adoption at our convention in September, and a

request that any of their members who had anything further to add on the subject would forward it either to their own secretary or to ours before the date of this meeting. We having heard nothing from them up to this time I assume that we will not, and I should be inclined to think that their committee stood ready to indorse our Committee's action, and that their association will indorse what their committee recommends.

The President. Your impression would be that they are waiting for the action of this convention?

Mr. Sherman. Precisely.

Mr. Brackett. I received, some time ago, a letter from the chairman of the committee on pipe specifications of the American Water Works Association, in which he stated that he should recommend for adoption the form of specification which was adopted by this Association.

It may be of interest to the members to hear the names of the pipe founders who have been consulted during the preparation of our report, as showing how wide a field was represented and the foundries which will be likely to accept these specifications if we adopt them. The manufacturers represented at our conferences were the United States Cast Iron Pipe and Foundry Company, which now owns and controls the cast-iron pipe plants at Burlington, N. J.; Buffalo, N. Y.; Scottdale, Pa.; Cleveland, Columbus, and Addyston, Ohio; Newport and Louisville, Ky.; Chattanooga, Bridgeport, and South Pittsburgh, Tenn.; Bessemer and Anniston, Ala., and West Superior, Wis. Messrs. R. D. Wood & Co. represented their plants at Camden and Florence, N. J.; and there were also represented the Donaldson Iron Company, Emaus, Pa.; the Warren Foundry and Machine Company's plant at Phillipsburg, N. J., and the plants at Lynchburg and Radford, Va. In all there were twenty foundries, represented by a committee which very carefully considered the specifications and consulted with us. I wish to say that the changes which have been made in the specifications since the preliminary draft was presented have been very largely the result of investigations which were made by the committee. Some of the changes, as you know, were suggested by members of the Association; some have resulted from our conferences with the manufacturers; some have been suggested to us by further study, and also by consultation with the pipe inspectors, who have, for many years, been acquainted with the best practice in the foundries, and who have given us their opinion as to the requirements necessary in order to obtain good castings.

Mr. Morris Knowles.* I am thoroughly in favor of standardization, whether it be of specifications or of statistics and accounts, but an incident that came under my observation some months ago has led me to wonder whether it will be entirely an advantage to have so many different classes of pipe. I will first tell the incident, and then I will ask a question. Something over 1 000 tons of pipe was wanted about, I think, Class C mentioned in these specifications. That does not happen to correspond with some of the standards of the Western foundries, which are heavier. After the bids were received, it was found that they were considerably in excess of the estimated cost of the work based upon standard prices current at that time for cast-iron pipe. Inquiry disclosed the fact that a certain percentage was added to the weights of pipe as they were designed, and a little increased price was charged besides that; in other words, the percentage added was not enough to bring it up to the standard of the pipe foundries in that part of the country, and therefore a little further percentage was added which, in fact, made the cost slightly more than it would have been if the standard of the various foundries had been taken. Of course, engineers desire, in specifying light weights, to save material, but if that cannot be done perhaps it is not an advantage to have so many classes. It looks, on the face of it, the manufacturers having suggested only four classes and the Committee having suggested five or more, as though possibly there might be something in their suggestion. I would, therefore, like to ask the Committee whether that matter came up in their discussions, and whether they think there is a reasonable surety that if light weights are used for certain works it will be an advantage in point of cheapness.

Mr. Coffin. I do not know that I can answer that question directly. Of course it is well known that the lighter the class the higher the price. In my own practice I have found that I could get the lighter weight cheaper, that is, for a smaller total cost, than I could get the heavier weight. But the Committee, as has been stated a number of times, felt that perhaps it was not their business, or the province of these specifications if adopted by the Association, to dictate to any engineer or any user of pipes what weights he should use; and besides that we wished the specifications to have as broad an application as possible. Now, I do know that there are engineers who are using pipe as light as anything we have provided for here,

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*Civil Engineer, Pittsburg, Pa.

and perhaps in some cases lighter; and while, perhaps, no member of the Committee would use the lightest weight, still it seemed just as desirable to provide for the use of those light weights as it did on the other hand to provide for the use of the heavy weights, and then let each engineer or user select whichever he saw fit, and if his lighter weights cost him more than his heavier weights, that is his business. We recognized, however, the desirability of having as much simplicity as possible. The whole matter has been quite thoroughly considered, and while the Committee would not presume to say that they have made absolutely the best arrangement, still, in our opinion, we have done as well as possible under the circumstances.

Mr. Knowles. Did the manufacturers' committee express any strong reasons why they recommended only four classes?

Mr. Coffin. I don't remember anything in particular. Possibly Mr. Brackett or Mr. Forbes may be able to answer that question.

Mr. Brackett. I think it was simply this, that the manufacturer would prefer to make two classes or only one class. But as the members of the Association have expressed their desire to purchase several classes or weights of pipe, the Committee felt that it ought to endeavor to provide for their desires, and we have tried to make as few classes as will meet all reasonable demands. I understand that the Western practice is not to make smaller sizes of pipe as light as are often used in New England.

Mr. E. H. Gowing.* I think Mr. Brackett has stated that about as it is, — that the pipe foundries would like to make as few classes as they possibly can. I think the specifications are good ones, they certainly have been prepared by as good men as there are in the water-works business, and I shall be very much disappointed if the Association does not adopt them. If it is proper to make such a motion at this time, I will move that the report of the Committee be accepted and that these specifications be adopted as the standard of the New England Water Works Association.

Mr. G. H. Benzenberg.† I am glad to see that the New England Water Works Association has given attention to that portion of water-works construction which heretofore has been pretty generally neglected. For the past twenty-five or thirty years particular attention has been given to those parts which are constantly visible, not only to the eye of the superintendent and operator, but also to the

* Civil Engineer, Boston, Mass. † Civil Engineer, Milwaukee, Wis.

eye of the community. The engineer and the superintendent have raised the requirements of their specifications from time to time, and the manufacturer has been willing to meet them, with the result that to-day we have pumping machinery which will develop a duty two or three times that which twenty-five or thirty years ago was supposed to be a fair average duty for pumping machinery. The distribution system of a water-works plant generally represents the largest item of cost. There is a greater sum of money invested in that branch of the works than in perhaps all the other branches taken together, and yet it has received the least attention. I dare say that only a comparatively small number of water-works managers have thought it necessary to have that branch of their work properly inspected, in order to secure compliance with the specifications, most of them accepting the pipe without inspection at the foundry. The result has been that gradually the pipe foundries have got into the habit of furnishing pipe from stock, which is undoubtedly for them the most convenient and economical arrangement.

The greater attention which has been given to boilers, pumping engines, etc., and which has resulted in supplying a much better class of machinery, was, and is undoubtedly, due to the increased economy which was obtained. It may be because the pipe distribution system is out of sight, and therefore largely out of mind, that less continuous attention has been given to its condition and to the economy which might be obtained from a better constructed and protected pipe. Nevertheless, as water-works plants are growing older, and these pipe distribution systems have been in service for a long time, examinations are being made, and it is found that they have very materially deteriorated in efficiency where soft or surface waters have been distributed, especially if the pipe was poorly prepared and indifferently coated. In some cities the standard requirements of specifications for pipe have, in recent years, been increased both as to the character of the iron and as to the method of casting, cleaning, and coating them.

Attention should be given to see, first, that the pipe is thoroughly cleaned, and it seems to me there is no better way of cleaning them than by the sand blast. By it you will remove all dirt or dust that may possibly be left upon the surface of the pipe, and the coating will then come in contact with the clean metal. The benefit of sand blasting has been very noticeable in the excellent results which have

been obtained. In draining the pipe after dipping into the bath, the coating does not peel off as it otherwise might have done at points where particles of dust or dirt had remained upon the pipe, and which points were left to corrode by the action of the water.

The coating also should receive particular attention. It has been the general custom of foundries to buy pitch from which all products of any commercial value have been extracted and which has been cut back with some dead oil, and put it in the tank for coating. The coating material should be as specifically and carefully prepared as any other article in the process of manufacture. Tests have been made to determine to what extent coal tar should be heated so as to evaporate only the lighter oils and restrain those which are beneficial to the residue as a coating for pipe. We cannot do too much in the way of studying and discussing this subject, and when we have arrived at a conclusion that it is best to raise the standard requirements in our specifications, they should then be so raised. It is for the engineer to determine, and for the contractors to furnish. The engineer should determine carefully what is required, and thereupon exact from the contractors a strict compliance with such requirements ; and I haven't any doubt that when it comes to them in that form they will meet the requirements of the engineer. They may ask an increased price for it, but will not the money be as well invested as it is in higher grade machinery, and won't as full a return be secured from it? I believe that the day will come when the engineer will see the increased benefit in pipe prepared to an ideal condition, and that he will specify such, that he will specify the pipe to be enameled, coating it, perhaps, with a porcelain enamel. What would be the result? He would have to pay from fifteen to twenty per cent. more for his pipe, certainly not over twenty per cent. more than the present cost of pipe, for such improved conditions. In return he would receive a pipe having from fifteen to twenty per cent. additional conveying capacity, besides which it would be in a condition to resist all corrosive action, even that of the electric current, and which would retain its full carrying capacity, probably, for the life of cast iron so protected, the period of which I don't believe I would want to state. The benefits to be derived from such pipe, it seems to me, would, as a water-works plant increases in age, be far in excess of the additional cost which would be entailed. I don't doubt but what to-day, if properly enameled water pipe were required, some manufacturer would meet the requirement, and if he did, others would have to follow if they wished

to remain in the business. It has been so in the construction of water-works pumping machinery, and I do not see why it should not be so in every other line of manufacture required by the water-works engineer.

For these reasons it seems to me that you have not set the requirements in these specifications any too high for the foundry men to meet. I am satisfied if you will insist upon the terms of your specifications, and that even if you were to make them much more stringent, the contractor will find it to his advantage to meet them, not at the cost at which he is supplying pipe as now furnished to the market, but at an additional cost, although such an additional cost will not be in excess of the advantage gained, and need not be prohibitive. In a contest which was had with some of the largest manufacturers of pipe, where the specifications were quite rigid, the contractors tried hard to have them amended, but the engineers insisted upon the requirements, and after some delay the manufacturers met them. They asked an additional price at first for the improved character of cleaning and coating, but I understand that to-day they are furnishing just such pipe without any additional charge, as they have found it to be just as cheap to clean them properly with the sand blast and to give them a better coating.

I did not expect to take so much of your time, Mr. President, and I did not come here prepared to say anything on this subject, but it is a matter in which we are all deeply interested, and one that is well worth our giving more attention and more study to in the future than it has received at our hands in the past.

The President. Mr. Benzenberg, to my knowledge, has made a careful study of this subject, and we all appreciate his having come from so great a distance to attend this convention and to address us. Does any other member of the Association wish to say anything upon the question? Mr. Hawley is called for.

Mr. W. C. Hawley.* I can merely indorse what Mr. Benzenberg has so well said. I believe I mentioned the matter of the sand blast in my remarks on this subject a year ago, and I have backed up my opinion by embodying it in specifications, at any rate, as an alternative. I think that the matter of coating is one which demands attention. It has received some attention, and some improvement has been made in that direction, but I believe that there is room for more. There is one matter which perhaps is

* Superintendent and Engineer, Pennsylvania Water Co., Wilkinsburg, Pa.

a little out of line, and yet it will follow immediately upon the adoption of such a set of specifications as has been presented, to which I would like to refer, and that is the importance of securing the enforcement of them.

In a case that came to my knowledge not long ago, a set of specifications was prepared, calling for certain material and certain results, and specifically stating certain conditions which would result in the rejection of the pipe, and a contract was awarded. A considerable quantity of the pipe was cast, and the inspector, who was a first-class man, a practical foundryman, and a man of perfect integrity, rejected practically all the pipe which he inspected. The engineer looked into the case and found that the inspector was perfectly right in rejecting the pipe under the specifications, and yet the contractor insisted that the pipe must be accepted, basing his insistence upon the claim that they were "commercial castings," as he termed it. That case is not yet settled. The pipe were not accepted, and the municipality was put to a very large expense, and the controversy will finally be threshed out in the courts. The municipality intends, I believe, to have it determined whether or not it has any rights which a contractor is bound to respect.

Now, that is what we find ourselves up against oftentimes when it comes to the enforcement of such specifications as these, and it is a matter which deserves the careful consideration of every superintendent and engineer.

Mr. Brackett. Mr. President, I do not know as I care to prolong the discussion, but I wish to say that I am very heartily in accord with the statements made by the last two speakers. I think there are many specifications for water pipe that contain provisions which are impracticable and which are therefore not enforced by the inspectors. I have discovered this during my visits to the pipe foundries during the past twenty years and from constant association with inpectors. I think, however, that the requirements of our proposed specifications can be enforced by an inspector, and that good work will be the result of such enforcement. I should be very glad to see a better protective coating and better cleaning of the pipe, and I think the time is coming when we shall have them. There is no reason why any member of this Association should not improve on these specifications, but for general practice it seems to me that the Committee has gone about as far as it is practicable to go at this present time. Some pipes for my own work are now being cleaned

by the sand blast and coated with what may be an improved coating, although time alone will decide. A number of years ago I made quite an extensive series of experiments for the purpose of obtaining a better coating than was then used upon pipes, but was not able to find anything at that time which I thought was practicable to use.

THE PRESIDENT. If there are any representatives of pipe foundries present, we hope they will not be bashful about speaking on this subject.

MR. ROBERT S. WESTON. I should like to ask the Committee if they considered the desirability of incorporating in the specifications anything in regard to the chemical constituents of the iron; that is, that there should not be more or less than a certain amount of carbon and different things of that character, as is customary in specifications for iron for some kinds of structural work.

MR. COFFIN. The Committee did consider that, and also a great many other things to which no reference has yet been made. I was very much interested in the discussion by Mr. Benzenberg, and by some of the other speakers, and it has suggested something to my mind which I wanted to speak of. I will say, to begin with, that I believe it has been the endeavor of the Committee to prepare specifications which would represent a high average practice; that is, if these specifications are followed, the pipe that is furnished will, in my opinion, be very much superior to the pipe that is furnished and used to-day, not, perhaps, by the Metropolitan Water Board, not by large cities and by the ablest engineers, but throughout the cities and towns where pipe is bought and used as it is to-day, necessarily, a great deal of it, without the advice of any engineer. I believe that if these specifications are adopted and enforced, very much superior pipe will be obtained in such cases. If these specifications are adopted by this and other associations, such action will undoubtedly result in their adoption by the foundries.

Now, in relation to higher requirements, I will say that that matter was considered, and it seemed to the Committee that those might be regarded as in the nature of pioneer requirements; for instance, the sand blast, superior methods of coating and chemical requirements, and all those things which can be readily asked for by any engineer, in addition to the requirements of these specifications. These specifications, perhaps, may be considered as a groundwork, a basis, and any refinements which may be desirable — and all this

pioneer work is desirable and necessary — can be introduced in addition, but it did not seem best to include them in a set of standard specifications which it is hoped will cover a wide range of practice.

Then another point which has been raised, is as to the enforcement of these specifications. I should like to say that to make them of any value, it is of the utmost importance, if they are adopted by the Association and favored by the members, for us all to see that when we buy pipe the provisions of the specifications are carried out, so far as we can do so; because if we simply order the pipe, and say that it must conform to the specifications of the New England Water Works Association, and then pay no more attention to the matter, we shall get the same pipe that we are getting to-day without specification. But I believe, as I have said before, that if these specifications are adopted and enforced, we shall get in a majority of cases very much better pipe than we have had in the past.

Mr. Edward V. French. I understand that this question of the number of classes has already been discussed to a considerable extent by members of the Association, but Mr. Knowles has brought the matter up again and I should like to ask whether, if members of the Association would like to have these specifications become the standard, it would not perhaps help them to win their way with the practical foundrymen if there were fewer classes. It seems to me as if the difference is so small that if we could get down to a few classes the foundrymen would make those regularly, and then if an engineer should desire to shade those classes on his own best judgment he could do so. Perhaps I may not understand the matter aright, but my point is this, that when we have so many classes the different superintendents and users of pipe may order first one class and then another, perhaps without any very great reason for their selection and distinction between the very small differences, with the result that the foundrymen will be a good deal bothered by these small shades of difference; and I wondered whether in the long run we could not get right down to three or four sizes which would represent good average practical conditions for the large majority of work, and then let the engineer, who is the man ordinarily to decide on these small differences, order any special size he wants, the specifications which the Association puts out representing something a little bit simpler.

Mr. Gowing. Mr. President, I think the Committee has got this down simple enough, and that really instead of shading these specifi-

cations at all they should be made more strict rather than less strict. As some of the previous speakers have said, let us make the specifications as we think they ought to be, and the foundrymen will live up to them. Just as they have done as to other kinds of machinery, they will do as to cast-iron pipe. Let us make the specifications such as they ought to be, specify what we want to get, and see that we get it, and in a short time the foundrymen will be making pipe just exactly as we want it, and by and by we can add the sand blast and all these other things.

Mr. French. Mr. President, if I may say just one word more, I think the gentleman does not quite get my point. I have no doubt that we can get just what we want if we know what that is; but the question is whether from a commercial standpoint there is any real gain in splitting the thing up so fine that the foundrymen have to carry all these different sizes, and whether we are not really making it cost us more than it would if we would let them come right down to three or four sizes and put all their energies right on to those. It is not a question of making our specifications better or more strict; that has nothing to do with it. It is just a question of commercial expediency. Now, I have no interest in the foundries, but as a general proposition I think it is true that in any kind of specifications for standard work the fewer the number of requirements the better. Of course if the commercial demands require so many sizes, all right, — that is something I don't know about, — but apparently this matter of the number of classes has not yet been satisfactorily settled in every one's mind, judging by what has been said here, and therefore I have ventured to bring it up again.

Mr. John C. Whitney.* As a matter of fact, Mr. President, it seems to me that these proposed specifications really simplify things for the foundrymen. As it has been in the past each water works of any size has had its own particular form of specifications, and the foundry people have been asked to bid on these special patterns which have been provided. Now, it seems to me that with these specifications the thing will be brought down to possibly five or six classes, and I should think that the foundrymen would really want a standard such as this is.

Mr. Brackett. The gentleman suggested having three or four classes. For sizes as high as ten inches there are only five classes, — there is one additional class on the 4-inch, but I think it would be

* Water Commissioner, Newton, Mass.

very seldom used, — and on classes above 10-inch the foundries seldom carry pipe in stock, so that the pipes would be made on orders in any case.

Mr. Benzenberg. These classes, it must be borne in mind, cannot be adhered to for all time to come. Changes in the thickness of pipe will necessarily be made as the quality of material is improved. The higher the grade of metal used, the thinner the shell of the pipe necessary to resist the strain. Undoubtedly during the past few years the quality of the metal has been much improved upon, and as I think it will be recognized that the limit has not yet been reached, these improvements will continue for years to come, and, necessarily, the thickness of the pipe will have to change. There is no necessity of wasting material by putting as much of the improved material into a pipe as was required to meet a certain strain with the old material, when you can do it with perhaps two thirds or three quarters of the former thickness of the shell. It seems to me for that reason that these classes which specify the various thicknesses can be modified before very long anyway, — just as soon as the foundries use a better quality of iron. They are now using a grade of iron with a tensile strength of from 24 000 to 28 000 pounds, whereas, perhaps only a few years back, the tensile strength was 16 000 to 18 000 pounds, and naturally the shell does not need to be so thick now as formerly. That is the distinction, as I understand, in these specifications, and they won't be likely to hold very long anyhow.

Mr. Gowing's motion to accept the report of the Committee and to adopt the specifications as the standard of the New England Water Works Association, was put and unanimously adopted.

Mr. Sherman. It seems to me it is not out of place at this time to suggest a vote of thanks to the Committee which has rendered us such able, and, I might say, distinguished service, and I therefore move that the thanks of the Association be given to Mr. Coffin and to Mr. Brackett and to Mr. Forbes.

Mr. Brackett. Mr. President, as one member of the Committee I wish to say that I feel I have only done my duty as a member of the Association, and I do not think that the Association should pass a vote of thanks to any of its members.

Mr. Coffin. I believe that is the view of the Committee as a whole.

Mr. Sherman. I will then withdraw the motion.

The President. I think I may be permitted to say that the Association appreciates the work that this Committee has done.

PROCEEDINGS OF THE TWENTY-FIRST ANNUAL CONVENTION.

September 10, 11, 12, 1902.

Boston, Mass.,
September 10, 11, 12, 1902.

The twenty-first annual convention of the Association was held at Boston, Mass., on Wednesday, Thursday, and Friday, September 10, 11, and 12, 1902. The headquarters of the Association during the convention were at the Hotel Brunswick, and the meetings were held in the banquet hall of the hotel.

The following members and guests were registered: —

Members.

Charles F. Allen, Francis E. Appleton, R. C. Bacot, Jr., M. N. Baker, Charles H. Baldwin, Lewis M. Bancroft, F. A. Barbour, Kenneth Allen, C. H. Bartlett, J. E. Beals, E. W. Bemis, G. H. Benzenberg, J. F. Bigelow, F. E. Bisbee, G. H. Bishop, J. W. Blackmer, W. L. Blossom, George Bowers, Dexter Brackett, E. C. Brooks, Fred Brooks, G. A. P. Bucknam, James Burnie, George Cassell, J. T. Cavanagh, G. F. Chace, E. J. Chadbourne, J. C. Chase, H. W. Clark, R. L. Cochran, W. F. Codd, F. C. Coffin, R. C. P. Coggeshall, D. W. Cole, M. F. Collins, B. I. Cook, H. A. Cook, F. H. Crandall, G. K. Crandall, J. W. Crawford, G. E. Crowell, A. W. Cuddeback, G. D. Curtis, J. M. Davis, C. E. Davis, A. O. Doane, L. S. Doten, E. R. Dyer, August Fels, B. R. Felton, C. R. Felton, J. N. Ferguson, G. W. Field, H. A. Fiske, Desmond FitzGerald, J. H. Flynn, F. F. Forbes, W. E. Foss, E. V. French, A. D. Fuller, S. De M. Gage, J. C. Gilbert, D. H. Gilderson, T. C. Gleason, A. S. Glover, W. J. Goldthwait, J. W. Goodell X. H. Goodnough, J. A. Gould, F. W. Gow, E. H. Gowing, J. W. Graham R. A. Hale, J. O. Hall, E. A. W. Hammatt, J. C. Hammond, Jr., L. M. Hastings, V. C. Hastings, L. E. Hawes, W. C. Hawley, Allen Hazen, F. W. Hodgdon, H. G. Holden, J. L. Howard, W. D. Hubbard, W. E. Johnson, E. J. Johnson, E. W. Kent, Willard Kent, Patrick Kieran, F. C. Kimball, Horace Kingman, Morris Knowles, C. F. Knowlton, E. S. Larned, R. S. Lea, A. A. Knudson, W. F. Learned, J. W. Locke, C. S. Lord, H. A. Lord, D. B. McCarthy, F. A. McInnes, H. V. Macksey, A. D. Marble, A. E. Martin, W. E. Maybury, F. E. Merrill, Leonard Metcalf, H. A. Miller, J. T. Miller,


21st Annual Convention N. E. Water Works Assn.

C. P. Moat, F. L. Northrop, P. D. O'Connell, C. B. Parker, W. W. Patch, W. Paulison, A. G. Pease, E. L. Peene, J. H. Perkins, T. F. Richardson, W. W. Robertson, P. P. Sharples, E. M. Shedd, C. W. Sherman, G. T. Staples, M. R. Sherrerd, M. A. Sinclair, H. E. Smith, J. Waldo Smith, G. H. Snell, H. T. Sparks, J. F. Sprenkel, G. A. Stacy, F. P. Stearns, N. W. Stearns, G. F. Swain, J. G. Tenney, R. J. Thomas, H. L. Thomas, W. H. Thomas, J. L. Tighe, S. Everett Tinkham, D. N. Tower, C. K. Walker, C. S. Warde, R. S. Weston, William Wheeler, J. C. Whitney, W. P. Whittemore, G. E. Wilde, F. I. Winslow, G. E. Winslow, E. T. Wiswall, L. R. Woods, E. P. Walters, C. J. Youngren. — 157.

Honorary Member.

F. W. Shepperd. — 1.

Associates.

Ashton Valve Co., by C. W. Houghton; Barr Pumping Engine Co., by J. O. Cheever; Harold L. Bond & Co., by Harold L. Bond; Builders Iron Foundry, by F. N. Connet; Chadwick-Boston Lead Co., by A. H. Brodrick and C. N. Fairbairn; Chapman Valve Mfg. Co., by E. G. Howard and Edward F. Hughes; Charles A. Claflin & Co., by Charles A. Claflin; Coffin Valve Co., by H. L. Weston; Wm. V. Briggs; Garlock Packing Co., by Horace A. Hart; Hersey Mfg. Co., by Albert S. Glover, J. A. Tilden, and F. C. Hersey, Jr.; International Steam Pump Co., by A. M. Pierce; Henry F. Jenks; Kennedy Valve Co., by M. J. Brosnan; Lamb & Ritchie, by Henry F. Peck; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; Charles A. Moore, by F. T. Tapley; H. Mueller Mfg. Co., by Adolph Mueller; John M. Holmes; Jenkins Bros., by H. F. Fiske, H. C. White, and J. D. Stiles; Library Bureau, by W. H. Britigan; National Meter Co., by Charles H. Baldwin, W. P. Oliver, and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey and D. B. McCarthy; Norwood Engineering Co., by H. W. Hosford; Perrin, Seamans & Co., by Charles E. Godfrey and James C. Campbell; Pittsburg Meter Co., by T. C. Clifford; Rensselaer Mfg. Co., by Fred S. Bates; Edward Robinson; Ross Valve Co., by William Ross; A. P. Smith Mfg. Co., by A. P. Smith and W. H. Van Winkle; Sumner & Goodwin Co., by F. D. Sumner; Sweet & Doyle, by H. L. DeWolfe; Thomson Meter Co., by Henry C. Folger and S. D. Higley; Union Meter Co., by C. L. Brown, F. L. Northrop, and A. S. Otis; U. S. Cast Iron Pipe and Foundry Co., by Edward T. Stuart; Walworth Mfg. Co., by George E. Pickering; R. D. Wood & Co., by Charles R. Wood; A. W. Chesterton & Co., by W. H. Greenwood; Stilwell-Bierce & Smith-Vaile Co., by F. H. Hayes. — 54.

Guests.

Michael Walsh (Water Commissioner), Yonkers, N. Y.; Mrs. W. H. Van Winkle, East Orange, N. J.; Mrs. T. C. Clifford, East Pittsburg, Pa.; S. B. Read, *Engineering News*, Boston, Mass.; Mrs. Helen M. Hawley and Mrs. Mary Stewart Miller, Wilkinsburg, Pa.; Mrs. Washington Paulison, Passaic,

N. J.; James P. Bacon, Cambridge, Mass.; George H. Partridge, *Engineering Record*, Boston, Mass.; Mrs. Adolph Mueller and Master William Everett Mueller, Decatur, Ill.; Mrs. Willard Kent, Narragansett Pier, R. I.; Edgar W. McCormack, Cuba; Fred C. Gifford and Hon. Murray D. Clement, Waltham, Mass.; Henry Eaton, Waltham, Mass.; John C. DeMello, New Bedford, Mass.; W. F. Whitman, Dedham, Mass.; Mrs. E. C. Brooks, Cambridge, Mass.; Herbert E. Whuttle, Knoxville, Tenn.; R. R. Swisher, Addison, Ohio; Mrs. F. N. Connet, Providence, R. I.; Mrs. W. H. Thomas, Hingham, Mass.; G. S. Walker, Dorchester, Mass.; C. T. Hawley and Miss Fannie L. Billings, Cambridge, N. Y.; E. L. Arundel, Frank L. Weaver, H. C. Taft (Members Water Board), Lowell, Mass.; R. A. Thayer, Woonsocket, R. I.; E. C. Gerrish, Tewksbury, Mass.; Mrs. George Bowers and Miss Ellen M. Weaver, Lowell, Mass.; Mrs. Lenor H. Knowlton, Miss A. M. Nightingale, Miss M. L. Gavin, Quincy, Mass.; Mrs. C. E. Davis, Upper Montclair, N. J.; Mrs. A. A. Knudson, New York City; Miss Helen F. Esmond and Mrs. D. B. McCarthy, Waterford, N. Y.; John Anderson, Binghamton, N. Y.; A. F. Hall, Marlboro, Mass.; Mrs. Charles S. Warde, Staten Island, N. Y.; Mrs. A. G. Pease, Spencer, Mass.; Mrs. C. W. Houghton. Boston, Mass.; Mrs. F. A. Houghton, Belmont, Mass.; Mr. M. C. Hyde, Springfield, Mass.; Mr. C. H. Allen, Boston, Mass.; Horace Ropes, South Framingham, Mass.; L. S. Cole, Kingston, Mass.; Fred A. Beals, Everett, Mass.; S. M. Spencer, Malden, Mass.; George A. Sanborn, William M. Collins, Lawrence, Mass.; Joseph T. Swan, Everett, Mass.; S. G. Johnson, Newton, Mass.; F. E. Hunter, W. F. Upham, and Miss J. M. Ham, West Newton, Mass.; Charles F. Merrill, Fred M. Hutchinson, Marion Merrill, W. E. Whitney, G. W. Snow, E. A. Binney, J. A. Durell, J. C. Taylor, Charles E. Childs, Fred S. Young, R. J. O'Malley, Thomas McNeill, and Harry Van Idinsture, Somerville, Mass.; H. B. Thoms, Mrs. James C. Campbell, F. A. Morrison, C. B. Moore, Edward W. Howe, Edward M. Hartwell, Mrs. J. D. Stiles, F. E. Lenaue, Boston, Mass.; James A. Bailey, Jr., Member Metropolitan Water and Sewerage Board, Arlington, Mass.; G. A. Winsor, Division Engineer, Metropolitan Water Works, South Framingham, Mass. — 82.

RECAPITULATION.

Members	157
Honorary Member	1
Representatives of Associates	54
Guests	82
	294
Counted twice	3
Total attendance	291

WEDNESDAY, SEPTEMBER 10.

The convention was called to order at 11 A.M., by President Merrill, who said: —

The hour appointed for this meeting has now arrived, and I have to announce the opening of the twenty-first annual convention of the New England Water Works Association.

We expected to have the pleasure this morning of listening to an address by his Honor Mayor Collins, but word has been received from him that it will be impossible for him to be with us, and we shall therefore be deprived of the pleasure which we had anticipated in listening to his remarks. I assure you, however, although I am not empowered to tender to you the customary official greeting of the city in which we are convened, that Boston extends to you a most cordial welcome, that the latchstring of hospitality is out for you in whatever direction you may wander, and that you are in the hands of friends whose endeavor it will be to see that this convention is both pleasant and profitable to you.

We have with us this morning a gentleman whom we have come to regard as a standby, and who has assisted us on numerous other occasions; I take pleasure at this time in calling upon Ex-Mayor John O. Hall, of Quincy, to say a few words to you.

Address of Welcome by Ex-Mayor John O. Hall, of Quincy.

Mr. President and Ladies and Gentlemen, Members and Friends of the New England Water Works Association: I confess I hardly know just the word to say to you at this time. I anticipated listening to the welcome of Mayor Collins, and I feel somewhat at a loss to know how to say the proper or fitting word. My only excuse for appearing before you is that I am willing and feel it my duty, as I always do, to respond to the request or command of my superiors. When our President requested me to say something this morning I hesitated at first; but thinking it might possibly relieve him somewhat of his embarrassment in the absence of the mayor, I consented to spend a few moments in trying to voice, if I might, something of the thoughts and feelings which fill our minds as we are here assembled.

Certainly Boston has for you, I know, a gracious welcome, and if the duties of its chief official do not permit him to be present to express it, I think you will be sure before the week ends that Boston does welcome you and that you will find, wherever you may go, she offers you every inducement and every encouragement to be bright and merry. I know how difficult it is sometimes when we meet in an assembly like this to throw off the labors and responsibilities and

burdens of life. We can come together for conference, we can grasp the glad hand, but back of it all and over it all there still rest the responsibilities of life, public and private, social and mercenary. But for a little while, at any rate, let us try to draw the curtain over all that, and for the present to enjoy ourselves to the limit; and I assure you that so far as I am personally concerned it will be my duty and pleasure, so far as I am able, to assist in every way possible in promoting the enjoyment of this occasion.

To my mind the power and the benefit of these conventions cannot be overstated or overestimated; and an obligation, it seems to me, rests upon every member of the organization to participate heartily in our duties and pleasures. It is the rubbing together, it is the sense of companionship, that gives us strength for carrying the burdens of life and its duties, and in such gatherings as this many things that trouble us and perplex us are oftentimes rolled away. You know how sometimes we will wake up in the night with a deep sense of oppression because of some responsibility, and how we will lie awake, perhaps, and toss and plan and figure the thing out, but when daylight comes the perplexity is all gone and the thing does not look at all as it did in the night. It is not half as ponderous and not half the bugbear it appeared to be. And it is just the same when we come into a convention of this kind. We say we will lock up our desks and we will drop our cares for a few days anyway, and we make a file of our papers and put them out of sight and come here and meet our neighbors and friends; and we discuss and we confer, we hear of their projects, and we try to help each other out of our difficult places, and when we go back and open our desks and take out our papers and take up our work again we find that our difficulties have solved themselves, matters have all been straightened out, and the things which seemed so burdensome to us before are now disposed of with ease and dispatch. You know the statement is made that there is no friendship that is so thoroughly cemented as the friendship which is formed over the broken bread. And so, when we get together in a convention like this, it makes us glad to be alive, and it simplifies our duties and helps us in every way. I trust that this will be the result of this meeting, and that when the week closes and we are obliged to say farewell, we will say that it has been the most helpful and most enjoyable convention that the New England Water Works Association has ever held.

NEW MEMBERS ELECTED.

The Secretary read the following names of applicants for membership, who were recommended by the Executive Committee: —

For Resident Member.

H. V. Macksey, Boston, Division Superintendent, Street Department.

Edward Phillip Walters, Boston, Biologist Metropolitan Water and Sewerage Board.

Fred J. Taylor, Westboro, Chief Engineer and Superintendent of Water Works at the Westboro Insane Hospital.

William E. Johnson, West Hartford, Conn., Assistant Engineer, Hartford Water Works, and Engineer for the Board of Water Commissioners of Hartford.

For Non-Resident Member.

Joseph T. Miller, Edgewood, Pa., with Pennsylvania Water Company.

John W. Hill, Philadelphia, Pa., Chief Engineer Bureau of Filtration.

I. A. Canals, Civil Engineer, Santurce, Porto Rico, City Engineer of San Juan.

For Associate.

The Stillwell-Bierce & Smith-Vaile Co., Boston, Steam and Power Pumping Machinery, Feed-water Heaters, Water Wheels, etc.

John M. Holmes, Philadelphia, Salesman.

Jenkins Bros., Boston, Manufacturers of Jenkins Bros.' valves, pump valves, and Jenkins' "96" sheet packing and other steam specialties.

On motion of Mr. Brackett, the Secretary was directed to cast the ballot of the Association for the applicants, which he did, and they were declared elected.

The Secretary read the following communication: —

BOSTON, September 10, 1902.

TO THE EXECUTIVE COMMITTEE OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

Gentlemen, — The constitution of our Association provides for the election to honorary membership of men eminent in work connected with hy-

draulic engineering or water supply. We have among our members one who for many years has been eminent in his profession, who has been intimately connected with some of the most important questions relating to water supply which have been under consideration in the United States. I refer to Mr. Alphonse Fteley, formerly Chief Engineer of the Croton Aqueduct Commission, and for many years connected with the engineering department of the Boston Water Works.

Mr. Fteley has taken a deep interest in this Association, and although always very busy and not physically strong, he has at considerable personal inconvenience on several occasions given the Association the benefit of his long and varied experience. On account of failing health Mr. Fteley has for several years not been able to continue the practice of his profession, but I know that he still takes an interest in all questions relating to water supply as well as in this Association. I believe that the grade of honorary membership in our Association should be given only to men eminent in their profession, and I also believe that no more fitting candidate for that grade of membership can be found than Mr. Alphonse Fteley, who I suggest be elected an honorary member of the Association.

Respectfully yours,

DEXTER BRACKETT.

The Secretary stated that the letter had been considered by the Executive Committee, and that the committee had unanimously voted to recommend Mr. Fteley for honorary membership.

On motion of Mr. Robert J. Thomas, the Secretary was directed to cast the ballot of the Association in favor of the election of Mr. Fteley as an honorary member, and this having been done, he was declared elected.

The meeting then adjourned till 2 P.M.

At the afternoon session the Hon. J. O. Hall, Ex-Mayor of Quincy, Mass., read a paper entitled, "Duties of Municipalities Regarding Water Supply." It was discussed briefly by Messrs. Freeman C. Coffin and M. N. Baker.

Mr. Freeman C. Coffin, Chairman of the Committee on "Standard Specifications for Cast-Iron Pipe," submitted the report of the committee. It was discussed by Messrs. Leonard Metcalf, Charles W. Sherman, Dexter Brackett, a member of the committee, Morris Knowles, G. H. Benzenberg, W. C. Hawley, F. N. Connet, Robert S. Weston, Edward V. French, and John C. Whitney; and on motion of E. H. Gowing the report was accepted and the specifications adopted as the standard of the New England Water Works Association.

At the evening session Mr. Frederic P. Stearns, Chief Engineer of the Metropolitan Water and Sewerage Board, gave an illustrated talk on "Recent Construction on the Metropolitan Water Works"; and Mr. Horace G. Holden, Superintendent, Nashua, N. H., read a paper on "The Water Supply of Nashua, N. H."

THURSDAY, SEPTEMBER 11.

At the opening of the morning session the following named were elected members of the Association: —

Non-Resident Member.

A. A. Knudson, New York, Electrical Engineer, engaged in investigation of the effects of electrolysis upon water-piping systems.

Associates.

Wm. V. Briggs, New York, Cast-iron and Wrought-iron Pipe, Supplies, etc.

Wm. H. Greenwood, Everett, Mass., Railway, Steamship, Mill and Water-works Supplies.

A paper giving a description of a new turbidimeter, contributed by Charles Anthony, Jr., Civil Engineer, Glenview, Hereford, England, was read by Charles W. Sherman. Remarks were made upon the subject of the paper by Messrs. Allen Hazen, F. N. Connet, and C. W. Sherman.

Mr. C. W. Sherman called attention to the fact that the constitution of the Association provides that at a business meeting during the annual convention a committee shall be appointed or elected, in such manner as the meeting shall see fit, to nominate officers for the ensuing year, and moved that the President be empowered to appoint such a committee. The motion was adopted, and the President appointed Messrs. Desmond FitzGerald, F. H. Crandall, Byron I. Cook, Joseph E. Beals, and V. C. Hastings as the committee.*

Mr. H. W. Clark, Chemist, Massachusetts State Board of Health, then read a paper on "The Removal of Color and Odor from Water."

The next business was the report of the Committee on "Apportionment of Charges for Private Fire Protection and the Means of

* Mr. FitzGerald having declined to serve, the President subsequently appointed Mr. George F. Chace in his place.

Controlling the Supply Thereto." Mr. F. H. Crandall, Chairman of the committee, reported that they had been unable to agree, and submitted a brief report in behalf of Messrs. Walker, Hammond, and himself; Mr. Edward V. French submitted a report concurred in by Messrs. Cook, Fiske, and himself; and Mr. John C. Chase presented an individual report.

Mr. Washington Paulison moved that Mr. Crandall's report be received and approved by the Association. The several reports were discussed by Messrs. Allen Hazen, W. C. Hawley, Frank C. Kimball, and R. C. P. Coggeshall, and the various members of the committee elaborated their positions.

Without action upon the report, upon motion of Mr. R. J. Thomas, the convention adjourned until 2 P. M.

Upon reassembling, Mr. Fred Brooks moved that the three reports be received and printed. The motion was seconded and adopted.

Mr. F. H. Crandall moved that the Chair appoint a committee of three water-works men, residing within fifty miles of one another, and within one hundred miles of Boston, to take up the question of Private Fire Services with committees of other societies. The motion was adopted.

Subsequently, on motion of Mr. F. C. Kimball, this vote was reconsidered. Mr. Kimball then presented a motion that the President appoint a committee of three, whose duty it shall be to ask for the appointment of and to confer with similar committees from the American Water Works Association, and other kindred associations, and also with the various underwriters' associations, to agree, if possible, upon some adequate means of controlling private fire supplies acceptable to all parties concerned, including therein all questions relating to charges therefor and similar matters. Mr. Crandall having accepted this as a substitute for his original motion, it was adopted.

On motion of Mr. Thomas, the committee was honorably discharged.

Mr. Allen Hazen, Civil Engineer, New York City, read a paper entitled, "The Physical Properties of Water." Mr. R. S. Weston discussed at some length the matters suggested by the paper.

Mr. Charles W. Sherman submitted, on behalf of the Committee on Uniform Statistics, its report. Dr. E. M. Hartwell, Secretary of the Boston Statistics Department, addressed the convention upon the subject of uniform statistics, after which, on motion of Mr. F.

H. Crandall, the report of the committee was accepted and its recommendations adopted. The committee was continued.

Mr. Henry F. Jenks, of Pawtucket, submitted the following report on Exhibits: —

List of Exhibitors at the Twenty-first Annual Convention.

Harold L. Bond & Co., Water Works Supplies, Boston.
Charles A. Claflin & Co., Water Works Supplies, Boston.
Coffin Valve Company, Boston.
Garlock Packing Company, Boston.
Hersey Manufacturing Company, Meters, Boston.
Henry F. Jenks, Drinking Fountains, Pawtucket, R. I.
Lamb & Ritchie, Tin Lined Iron Pipe, Cambridge, Mass.
Lead Lined Iron Pipe Company, Wakefield, Mass.
H. Mueller Manufacturing Company, Water Works Supplies, Decatur, Ill.
National Meter Company, Meters, New York City.
Neptune Meter Company, Meters, Long Island City, N. Y.
Perrin, Seamans & Co., Water Works Supplies, Boston.
Pittsburg Meter Company, Meters, East Pittsburg, Pa.
Edward Robinson, The Wells Light, New York.
A. P. Smith Manufacturing Company, Tapping Machines, Newark, N. J.
Sumner & Goodwin Company, Water Works Supplies, Boston.
Sweet & Doyle, Vincent Valves, Boston.
Thomson Meter Company, Meters, Brooklyn, N. Y.
Union Water Meter Company, Meters, Worcester, Mass.
Walworth Manufacturing Company, Water Works Supplies, Boston.
Jenkins Brothers, Valves, Packing, etc., Boston.
N. W. Stearns, Water Filter, Roxbury, Mass.
F. W. Gow, Meter Testing Apparatus, Medford, Mass.
Stillwell-Bierce & Smith-Vaile Company, Pumps, Dayton, Ohio.
A. W. Chesterton & Co., Water Works Supplies, Boston.
Library Bureau, Card Filing Devices, Boston.

The report was accepted.

The following new members were elected: —

Resident Members.

John W. Lynch, Brookline, Engineer at Pumping Stations Boston and Metropolitan Water Works.

Harold K. Barrows, Assistant Professor of Civil Engineering at the University of Vermont, Burlington, Vt.

Associate.

Library Bureau, Boston, Makers of Card Index Systems.

The President. This concludes the more formal proceedings of this convention, to-morrow being devoted to our excursion. Personally, and I think I may say in behalf of the entire official staff, I desire to thank you for the interest which you have manifested in our work by your attendance at the meetings, and for the support and encouragement which you have given your officers in the performance of their duties. If there is no other business to come before the meeting we will now adjourn.

The convention then adjourned until evening.

At the evening session, Mr. Desmond FitzGerald, Engineer Sudbury Department, Metropolitan Water Works, gave an illustrated talk on "What an Engineer Saw in Venice."

Mr. R. C. P. Coggeshall, of New Bedford, gave an historical address, "Twenty Years After: A Retrospect."

EXCURSION TO METROPOLITAN WATER WORKS.

Friday, September 12, 1902.

Friday, September 12, was devoted to a visit to the Wachusett Dam and North Dike, at Clinton, and the Weston Aqueduct and Reservoir in Wayland and Weston. A special train, furnished by the courtesy of the Boston & Maine Railroad Company, left the North Union Station at 8.45 a.m., and arrived at the dam at Clinton about 10 a.m. After inspecting the work at the dam, the party walked to the North Dike, a distance of about one mile, where the soil which is being stripped from the reservoir is being deposited. A short distance below the dam a tunnel and the pedestals for a viaduct on the re-location of the Central Massachusetts Railroad may be seen.

The party returned to the dam and took the train promptly at 11.40 a.m., for Wayland, where it arrived at 12.25 p.m. Lunch was served at the Town Hall in Wayland. After lunch the Association was called to order by the President, and upon motion of Mr. Coggeshall the thanks of the Association were voted to the Boston & Maine Railroad Company and to the Metropolitan Water and Sewerage

Board, for courtesies extended. At 1.30 P.M. barges were taken for a drive of about twelve miles along the line of the Weston Aqueduct. The laying of riveted steel pipe seven feet in diameter, the construction of the masonry aqueduct and of the Weston Reservoir were inspected. At the crossing of the Charles River the construction of a coffer dam, which is to be used in laying three lines of 60-inch pipes under the river, was seen. The party returned to Boston on a train leaving Auburndale at 5.45 P.M., reaching Boston at 6.12 P.M.

The program and statistics relating to the works visited are as follows: —

Commonwealth of Massachusetts.

METROPOLITAN WATER WORKS.

VISIT OF THE NEW ENGLAND WATER WORKS ASSOCIATION TO THE WACHUSETT DAM AND DIKE AND TO THE WESTON AQUEDUCT, RESERVOIR, AND PIPE LINES, FRIDAY, SEPTEMBER 12, 1902.

The forenoon program includes an inspection of the work at the Wachusett Dam, at the North Dike, and along a portion of the relocation of the Central Massachusetts Railroad in the vicinity of the dam. The party will arrive at the dam at about 10.00 A.M., and will start to walk from the dam to the North Dike at 10.30. The trip to the North Dike will extend only to the middle of the easterly portion, and the party will return without delay, reaching the dam again about 11.15.

The remaining time can be spent in examining the tunnel and other work on the relocation of the railroad a short distance below the dam, and in further inspection of the dam.

Those who wish to see the central power plant which furnishes compressed air for all operations at the dam, quarry, and tunnel, and the quarry from which stone for the dam is obtained, can do so by omitting the trip to the North Dike, and after visiting these works they may take the train at 11.50, at the platform on the Central Massachusetts Railroad just west of the power station.

The train will leave the dam promptly at 11.40 A.M.

The afternoon program includes an inspection of points of interest on the easterly half of the Weston Aqueduct and of a portion of the pipe line which is to convey water from the aqueduct to a point near Chestnut Hill Reservoir.

Opportunity will be given to inspect the laying of riveted steel pipe 7½ feet in diameter, the construction of the masonry aqueduct with special

appliances for crushing, screening, and mixing concrete at Section 11, the construction of the Weston Reservoir, the building of a coffer dam which is to be used in laying three lines of 60-inch cast-iron pipes under the Charles River, and pipe laying in the Newton Boulevard.

Statistics.

Wachusett Dam.

Length of main dam between terminal structures	850 feet.
Length of waste weir	450 feet.
Height of top of main dam above full-reservoir level	20 feet.
Maximum height of dam above rock foundation, about	205 feet.
Present height of dam above rock foundation, about	85 feet.
Maximum thickness of dam at bottom, about	185 feet.
Thickness of dam at full-reservoir level	25 feet.
Maximum depth of water above dam	129 feet.
Masonry required for dam	280 000 cu. yds.
Contractor	McArthur Brothers Company, of Chicago.
In charge of work for contractor	Winston Brothers and Locher.
Amount of contract	$1 603 635.
Date specified for completion of dam	November 15, 1904.

The air-compressing plant includes: two double Rand compressors, operated by two compound, condensing Corliss engines of 500 horse-power each.

The two Lidgerwood cableways at the dam have each a span of 1,150 feet, and a capacity of 8 tons. The easterly and westerly movable towers which support the cableways are, respectively, 60 and 90 feet in length.

North Dike.

Length on water side	2 miles.
Height to full-reservoir level at deepest place	65 feet.
Maximum width of base	1 930 feet.
Area covered by dike	143 acres.
Contents of dike	5 500 000 cu. yds.
Total length of cut-off trench	9 556 feet.
Length of cut-off trench excavated to solid rock	3 124 feet.
Length excavated to fine sand	6 432 feet.
Length of cut-off trench where sheet piling was driven	5 245 feet.

Wachusett Reservoir.

Area of watershed	118.23 sq. miles.
Elevation of water level of full reservoir above Boston city base (low tide)	395 feet.
Water surface, 4 195 acres, or	6.56 sq. miles.
Total contents	63 068 000 000 gals.
Length	8.41 miles.
Maximum width	2.05 miles.
Maximum depth	129 feet.
Average depth	46 feet.
Total length of shore, not including islands	35.4 miles.
Length of railroad flooded	6.56 miles.
Length of highways flooded	19.21 miles.

The land required for this reservoir contained 6 large mills, 8 schoolhouses, 4 churches, and about 360 dwelling-houses occupied by upwards of 1 700 people.

The buildings, vegetation, and surface soil are being removed from the reservoir. The soil has been removed from about two thirds of the area of the reservoir, and at the end of this year the area stripped will be about four fifths of the whole.

Relocation of Central Massachusetts Railroad.

The new line of the railroad is to leave the present line just west of the bridge over the New York, New Haven & Hartford Railroad at West Berlin, and it will run so as to pass over the valley of the Nashua River just below the dam, then continuing along the shore of the reservoir to the North Dike, and across the dike behind its crest to a junction with the Worcester, Nashua & Portland Division of the Boston and Maine Railroad, which it will follow to Oakdale.

There is unusually heavy work on the line of the railroad, including a tunnel 1 063 feet long on the easterly side of the Nashua River, a viaduct 917 feet long across the valley of the river, with a maximum height above the bed of the river of 132 feet, and a rock cut having a maximum depth of 60 feet on the westerly side of the river.

Weston Aqueduct.

The aqueduct, starting at the Sudbury Dam, runs easterly for a total distance of 13.44 miles, through the towns of Southboro, Framingham, Wayland, and Weston, to the high land a short distance west of the Charles River nearly opposite Norumbega Park.

For the first $3\frac{1}{2}$ miles it was feasible to obtain a fall of 4 feet in 5 000, while for the remainder of the distance down to the reservoir only 1 foot in 5 000; consequently the aqueduct, although everywhere of a daily capacity of 300 000 000 gallons, is of different sizes, the upper portion being 10 feet wide by 9 feet 3 inches high, and the lower portion 13 feet 2 inches wide by 12 feet 2 inches high.

The aqueduct is constructed chiefly of concrete masonry, but the lower half has a lining of one course of brick masonry.

There are several special sections, as follows: —

Three 5-foot cast-iron pipe-lines from Sudbury Dam to head-house.

One $7\frac{1}{2}$-foot riveted steel pipe-line across the Sudbury River and Happy Hollow valleys, having, respectively, lengths of 3 603 and 1 123 feet, to be supplemented in the future by two additional lines.

Five tunnels to be lined with Portland cement concrete, and having a total length of 2.30 miles.

An open channel $\frac{1}{4}$ of a mile long, in Weston, just above the reservoir.

The estimated cost of the aqueduct, including the reservoir, is about $3 200 000.

Weston Reservoir.

The Weston Reservoir and open channel leading to it have a total length of about a mile, and for this distance the masonry aqueduct will be omitted.

The lower end of the reservoir is rather more than a mile above the terminus of the aqueduct. It is constructed for the purpose of equalizing the flow of water and preventing the aqueduct from being surcharged toward its lower end.

The area of the reservoir is 60 acres, or just half that of Chestnut Hill Reservoir.

The minimum depth will be 11 feet and the maximum depth 28 feet.

The surface of the reservoir will be 200 feet above mean low water, making it 37 feet above Spot Pond and 66 feet above Chestnut Hill Reservoir.

The dam will be constructed of earth, with a core-wall of concrete masonry resting upon rock.

Drains will convey all polluted and nearly all other local water past the reservoir into the brook below it.

Supply Pipe Lines.

From the terminal chamber of the aqueduct, the water is to be distributed to different points in the Metropolitan Water District through cast-iron pipes running in different directions.

One line of pipes is now being laid through the city of Newton, much of the way through the Newton Boulevard, as far as Chestnut Hill Reservoir, where it will connect with existing pipes. This line, which is 7.4 miles long, is 60 inches in diameter from the terminal chamber to the easterly side of the Charles River, and 48 inches in diameter for the remaining distance.

November Meeting.

Hotel Brunswick, Boston,
November 12, 1902.

President Frank E. Merrill in the chair; Willard Kent, Secretary.

The following members and guests were in attendance: —

Members.

Charles H. Baldwin, L. M. Bancroft, J. E. Beals, George Bowers, Dexter Brackett, E. C. Brooks, Fred Brooks, G. F. Chace, J. C. Chase, F. C. Coffin, R. C. P. Coggeshall, L. E. Daboll, L. S. Doten, J. N. Ferguson, H. F. Gibbs, Albert S. Glover, Amos A. Gould, John O. Hall, V. C. Hastings, T. G. Hazard, Jr., H. G. Holden, Willard Kent, G. A. Kimball, L. P. Kinnicutt, C. F. Knowlton, A. E. Martin, F. E. Merrill, H. V. Macksey, F. L. Northrop, J. H. Perkins, W. W. Robertson, E. M. Shedd, C. W. Sherman, G. T.

Staples, G. A. Stacy, R. J. Thomas, H. L. Thomas, W. H. Thomas, D. N. Tower, G. W. Travis, W. H. Vaughan, R. S. Weston, G. E. Winslow. — 43.

ASSOCIATES.

Ashton Valve Co., by C. W. Houghton; Barr Pumping Engine Co., by William McLaughlin; Harold L. Bond & Co., by Harold L. Bond; Builders Iron Foundry, by F. N. Connet; Chapman Valve Mfg. Co., by Edward F. Hughes; Charles A. Claflin & Co., by Charles A. Claflin; Coffin Valve Co., by H. L. Weston; A. W. Chesterton & Co., by W. H. Greenwood; Hersey Mfg. Co., by Albert S. Glover and Francis C. Hersey, Jr.; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Perrin, Seamans & Co., by James C. Campbell; Thomson Meter Co., by S. D. Higley; Union Water Meter Co., by Frank L. Northrop; United States Cast Iron Pipe and Foundry Co., by W. B. Franklin. — 19.

GUESTS.

W. A. Daggett, Jr., Natick, Mass.; J. F. Gleason, Quincy, Mass.; George H. Partridge, *Engineering Record*, Boston, Mass.; Prof. Ira N. Hollis, Harvard University, Cambridge; Prof. Edward F. Miller, Massachusetts Institute of Technology, Boston. — 5.

(Names counted twice. — 3.)

The Secretary read the names of the following applicants for membership, who were recommended for election by the Executive Committee: —

For Resident Member.

George A. Sanborn, Superintendent, Essex Company, Lawrence, Mass.

Harry E. Barnard, Chemist, State Board of Health, Concord, N. H.

D. A. Heffernan, Superintendent of Water Works, Milton, Mass.

For Non-Resident Member.

Robert E. Horton, Hydrographer, U. S. G. S., Utica, N. Y.

John W. Alvord, Civil Engineer, Chicago, Ill.

David Dexter Clarke, Engineer of Water Committee, Portland, Ore.

J. H. Ince, Assistant to President, Western New York Water Co., Buffalo, N. Y.

William R. Conard, Inspector of Materials, Burlington, N. J.

R. O. Wynne-Roberts, Water Engineer to the City of Capetown, South Africa.

On motion the Secretary was directed to cast the ballot of the Association for the applicants, which he did, and they were declared elected.

A letter from Mr. Alphonse Fteley, accepting his election as honorary member, was read by the Secretary.

The President announced his appointment of Messrs. F. H. Crandell, R. J. Thomas, and Elbert Wheeler, as the Committee on Private Fire Services, in accordance with a vote passed at the convention in September.

Prof. Ira N. Hollis, of Harvard University, was introduced, and spoke on the economic use of fuel in steam plants. Prof. L. P. Kinnicutt, in discussion, spoke of the chemist's views of combustion and of some chemical methods of attaining high temperatures.

Prof. Edward F. Miller, of the Massachusetts Institute of Technology, read a paper on "The Sulphurous Anhydride Waste-heat Engine."

Adjourned.

MEETINGS OF THE EXECUTIVE COMMITTEE.

The Executive Committee met before the meeting of the Association on September 10; present, President Merrill, Messrs. Kent, Brooks, Bancroft, Hammond, Holden, Stacy, Thomas, C. W. Sherman, and Walker. Applications for membership were approved. A letter was received from Mr. Dexter Brackett, suggesting the election of Mr. Alphonse Fteley as an honorary member of the Association. It was voted that the Executive Committee recommend the election of Mr. Fteley as an honorary member.

Adjourned.

The Executive Committee met at Tremont Temple, on October 16, 1902. The question of the place for holding the November meeting was raised, and after discussion it was unanimously voted that it be at the Hotel Brunswick.

The editor, Mr. Sherman, brought up the question of a general index to the JOURNAL. He said that for more than two years he has been trying to prepare such an index, but had not yet succeeded in making much progress. It was voted that Mr. Sherman be authorized to confer with the Library Bureau regarding the preparation of such an index.

Adjourned.

The Executive Committee met at Tremont Temple, at 11.30 A.M.; present, President F. E. Merrill, Secretary Willard Kent, and Messrs. Brooks, Thomas, Holden, Bancroft, C. W. Sherman, and Stacy. Nine applications for membership were approved. The Editor, Mr. Sherman, reported the result of his conference with the Library Bureau, regarding the preparation of a general index to the JOURNAL, and it was voted that he be authorized to have such an index prepared and printed.

Adjourned.

After the meeting of the Association on November 12, the Executive Committee again came together and voted unanimously to hold all the winter meetings at the Hotel Brunswick.

Adjourned.

OBITUARY.

George A. Hotchkin, superintendent of the Bureau of Water, Rochester, N. Y., died in that city on October 6, 1902.

Mr. Hotchkin was born in Caledonia, N. Y., in 1853, but his parents removed to Rochester while he was an infant. He was educated in the Rochester schools, and fitted himself for the profession of civil engineering. In 1874 he began work on the engineering force in connection with the first conduit from Hemlock Lake, and, with the exception of three or four years spent in contracting work, had been connected with the water department of Rochester continuously since that date. He became superintendent on January 1, 1900. His long experience in the department had familarized him with all its details, and he was regarded by superiors and subordinates alike as a faithful and capable official.

He was stricken suddenly while dining at the Whist Club, in company with City Engineer Fisher, and lived but little more than an hour. He is survived by his wife.

The following resolution was adopted by the heads of the city departments: —

Death has struck down without notice our comrade and genial companion, George A. Hotchkin, superintendent of water works. It is fitting that we should voice the sentiment which we all feel, that Rochester has lost an able, honest, and efficient official and a good citizen, and we have lost a liberal-minded, kind-hearted friend. We extend to his dearly beloved wife our heartfelt sympathy in this her direst bereavement.

Mr. Hotchkin was elected a member of the New England Water Works Association on June 13, 1900.

BOOK NOTICES.

"The Municipal Year Book, 1902; Giving the Population, Assessed Valuation, Principal Officials, and Ownership of Public Utilities, also Information regarding the Water Supply, Sewerage, Street Cleaning, Street Sprinkling, Garbage, Fire and Underground Electric Service in all Incorporated Places in the United States, and in all New England Towns of 3 000 Population and Upwards by the Census of 1900. With Summaries and Editorial Discussion." Edited by M. N. Baker, Ph.B., C.E., Associate Editor of *Engineering News*, Editor of the *Manual of American Water Works*, etc. Engineering News Publishing Co., New York. $3.00.

This is indeed "an encyclopædia of municipal news and statistics." The various statistics listed in the sub-title are given briefly for each city or town in the body of the book, and, in addition, the information of most general interest is tabulated or summarized in the introduction, and so arranged as to show the extent of municipal and private ownership of the several public utilities. A table of water purification plants, showing for each municipality where the water is purified, the kind of purification, ownership of works (whether public or private), and population may be noted as an example of especial interest to Association members, and typical of the manner in which information has been summarized for ready reference and for comparison.

"The Graphical Solution of Hydraulic Problems; Treating of the Flow of Water through Pipes, in Channels and Sewers, over Weirs," etc. By Freeman C. Coffin, M. Am. Soc. C. E. Second edition, revised and enlarged. John Wiley & Sons. New York.

This valuable hand-book is already well known and generally appreciated. It contains tables and diagrams by which all the ordinary hydraulic problems may be quickly solved with explanatory text. The second edition has been enlarged by the addition of several new diagrams and a brief discussion of the flow of water in riveted steel pipes.

New England

Water Works Association

ORGANIZED JUNE 21, 1882.

CONSTITUTION

AND

LIST OF MEMBERS.

MARCH, 1901.

BOSTON, MASS.:
W. N. HUGHES, 52 PURCHASE ST.
1901.

PRESIDENTS

OF THE

New England Water Works Association.

*James W. Lyon, 1882–83.

Frank E. Hall, 1883–84.

George A. Ellis, 1884–85.

Robert C. P. Coggeshall, 1885–86.

Henry W. Rogers, 1886–87.

*Edwin Darling, 1887–88.

*Hiram Nevons, 1888–89.

Dexter Brackett, 1889–90.

*Albert F. Noyes, 1890–91.

Horace G. Holden, 1891–92.

George F. Chace, 1892–93.

George E. Batchelder, 1893–94.

George A. Stacy, 1894–95.

Desmond FitzGerald, 1895–96.

*John C. Haskell, 1896–97.

Willard Kent, 1897–98.

Fayette F. Forbes, 1898–99.

Byron I. Cook, 1899–1900.

Frank H. Crandall, 1901.

* Deceased.

CONSTITUTION OF

The New England Water Works Association,

Adopted September 19, 1900.

ARTICLE I.

NAME AND OBJECT.

SECTION 1. The name of this society shall be THE NEW ENGLAND WATER WORKS ASSOCIATION.

SECT. 2. Its objects shall be the advancement of knowledge relating to water works and water supply, and the encouragement of social intercourse among water works men.

ARTICLE II.

SECTION 1. The membership of the Association shall consist of Members, Honorary Members, and Associates.

SECT. 2. Water works superintendents or other executive officers, commissioners or members of Water Boards, hydraulic engineers, sanitarians or other persons qualified to aid in the advancement of knowledge relating to hydraulic questions, shall be eligible as Members.

SECT. 3. Members only shall be eligible to office and entitled to the right to vote.

SECT. 4. Associates shall be firms or representatives of firms engaged in dealing in supplies used by water works.

SECT. 5. Members hereafter elected engaging in the business of furnishing water works supplies shall cease to be Members of the Association and their names shall be transferred to the list of Associates.

SECT. 6. Associates shall be entitled to representation at each meeting of the Association, but shall not be entitled to vote or take part in any discussion unless permission is given by the meeting.

Sect 7. Honorary Members shall be men eminent in some line of work connected with hydraulic engineering or water supply.

Sect. 8. Members shall be classed as Resident or Non-Resident; the former comprising residents of the New England States, all others being Non-Resident Members.

ARTICLE III.

ADMISSIONS AND EXPULSIONS.

Section 1. An application for admission to the Association as Member or Associate shall embody a concise statement of the candidate's qualifications for membership, and shall be endorsed by two Members of the Association.

Sect. 2. Applications for membership shall be considered by the Executive Committee, who shall present them to the Association for ballot, provided a majority are in favor of such action.

Sect. 3. Election to membership shall be by ballot, and shall require two-thirds of the ballots cast.

Sect. 4. Members and Associates elect shall subscribe their names to the Constitution by signing a form to be furnished by the Secretary.

Sect. 5. Any person who shall be in arrears to the Association for two years' dues shall be notified by the Secretary that if payment is not made within three months his name will be dropped from the roll; and if such arrears are not paid within the time specified, the Secretary shall erase the name from the membership list.

Sect. 6. A member of any grade may withdraw from the Association by giving written notice to the Secretary and settling all indebtedness to the Association.

Sect. 7. A member of any grade may be expelled from the Association upon the recommendation of the Executive Committee, adopted by a two-thirds vote of the members present and voting at any regular meeting.

ARTICLE IV.

DUES.

Section 1. The Initiation Fee shall be

For Resident Members	$5 00
For Non-Resident Members	3 00
For Associates	10 00

Sect. 2. The Annual Dues shall be

For Members	$3 00
For Associates	15 00

which shall include a subscription to The Journal of the New England Water Works Association.

Sect. 3. A person transferred from the grade of Member to that of Associate shall not be assessed an additional initiation fee, but shall be liable for dues as an Associate.

ARTICLE V.

OFFICERS.

Section 1. The officers of this Association shall be a President, six Vice-Presidents, not more than three of whom shall be residents of the same State, a Secretary, and a Treasurer; these, together with the Editor and Advertising Agent of The Journal of the New England Water Works Association and three other members, shall constitute the Executive Committee, in whom the government of the Association shall be vested.

Sect. 2. The term of office of all officers and committees shall be one year, but shall continue until their successors are duly elected.

Sect. 3. There shall also be a Finance Committee of three Members of the Association other than members of the Executive Committee.

Sect. 4. All officers and Committees shall assume their duties immediately after the close of the meeting at which they have been elected.

ARTICLE VI.

DUTIES OF OFFICERS.

Section 1. The President shall have a general supervision of the affairs of the Association. He shall preside at meetings of the Asso-

ciation and of the Executive Committee. In case of his absence or a vacancy in his office, the Vice-Presidents in order of seniority shall discharge his duties.

Sect. 2. The Executive Committee shall have full control of the management of the Association, subject to the action of the Association at any meeting. They shall make the necessary arrangements for all meetings, and shall have power to expend the funds of the Association, provided that no indebtedness shall be incurred in excess of the funds in the hands of the Treasurer. All questions in Executive Committee shall be decided by a majority vote, and six members shall be a quorum. The Executive Committee shall hold meetings at the call of the President, or, in his absence or inability to serve, at the call of the senior Vice-President.

Sect. 3. The Secretary shall conduct the official correspondence of the Association, shall collect and receipt for all fees and dues, and transmit the same to the Treasurer quarterly, taking his receipt therefor; he shall issue notices of all meetings of the Association at a date not less than two weeks prior to the time appointed for such meetings. He shall make a report to the Association at the annual meeting of the general condition of the Association and especially of changes in the membership.

Sect. 4. The Treasurer shall receive from the Secretary all moneys collected by him for the Association, giving his receipt therefor, and shall pay all demands against the Association when approved by the President. He shall keep a proper account of all receipts and expenditures, and shall make a report to the Association, at the annual meeting, of his doings as Treasurer during the year preceding, together with a statement of the financial standing of the Association.

Sect. 5. The Finance Committee shall meet on or before the day of the annual meeting and shall audit the accounts of the Secretary and Treasurer. They shall hold such other meetings as the interests of the Association may require.

Sect. 6. The proceedings of the Association shall be published as The Journal of the New England Water Works Association, which shall be issued quarterly, under the direction of a Board of Editors, consisting of the President and Secretary, *ex-officiis*, and the Editor and Advertising Agent chosen by ballot. The Journal shall contain such portion of the record of any meeting as the Board

of Editors may deem it expedient to publish, as well as any other articles which they shall consider of interest to the Association.

SECT. 7. The Editor of THE JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION shall, under the direction of the Board of Editors, keep and prepare for publication all matters intended to be printed in the Journal, and shall act as the executive officer of the Board of Editors. He shall present a report at the annual meeting, showing in detail the cost of publication of the Journal and the receipts from advertising and subscriptions.

ARTICLE VII.

NOMINATION AND ELECTION OF OFFICERS.

SECTION 1. At the business meeting during the annual convention the Associaton shall elect or appoint, in such manner as may be approved by the meeting, a Nominating Committee of five members, who shall present a report before the first day of November in the form of a list of nominations for officers for the ensuing year. This report shall be printed and mailed by the Secretary to the membership of the Association.

SECT. 2. At any time before December 1, any ten or more Members of the Association may send to the Secretary additional nominations signed by such Members.

SECT. 3. The Secretary shall issue a printed ballot on the fifteenth day of December, which shall contain the nominations made by the Nominating Committee and such other nominations as may have been received by him in accordance with Section 2. This ballot shall be mailed to all members entitled to vote.

SECT. 4. Ballots may be sent by mail to the Secretary or handed to him directly. They must be enclosed in two sealed envelopes, and the outer envelope shall be endorsed by the voter's signature.

SECT. 5. The polls shall be closed one hour after the time of opening the Annual Meeting, and the ballots shall be canvassed by tellers appointed by the presiding officer. The persons receiving the highest number of votes for the offices for which they are candidates shall be declared elected.

ARTICLE VIII.

MEETINGS.

SECTION 1. A Convention of the Association for the reading and discussion of papers and for social intercourse shall be held annually

at such time and place as may be determined by the Executive Committee.

SECT. 2. There shall be two general business meetings of the Association each year; first, the annual meeting, which shall be held in Boston on the second Wednesday in January, and at which the annual reports for the year ending December 31 shall be presented, and the ballot for officers canvassed; and second, a business meeting during the annual convention.

SECT. 3. In addition to the above, business meetings shall be held on the second Wednesday of the months of November, December, February and March, and, at the discretion of the Executive Committee, in June.

SECT. 4. At any business meeting of the Association, twenty members shall constitute a quorum.

SECT. 5. All regular meetings of the Association, except the annual convention, shall be held in Boston, unless otherwise voted by the Executive Committee.

SECT. 6. Special meetings of the Association may be held at the call of the President. At special meetings no applications for membership shall be considered, and no business shall be transacted, unless announced in the call for the meeting and on the recommendation of the Executive Committee.

SECT. 7. Meetings of the Executive Committee shall be held before each business meeting of the Association and at such other times as the President may deem necessary.

ARTICLE IX.

AMENDMENTS.

SECTION 1. Proposed amendments to this Constitution must be submitted in writing to the Executive Committee, and shall be presented to the Association at a regular meeting, if so decided by vote of the committee. It shall be the duty of the Executive Committee to bring before the Association any proposed amendment at the written request of ten members.

SECT. 2. Announcements of a proposed amendment which is recommended by the Executive Committee, or by ten members of the Association, shall be given by printing the amendment in the notices of the regular meeting. A two-thirds vote of the members present and voting shall be necessary for the adoption of an amendment.

LIST OF MEMBERS,

WITH ADDRESS AND DATE OF ELECTION.

Name.	Date of Election.
Abbot, Everett L. 236 Eighth Avenue, New York City.	June 9, 1892
Adams, John D. Supt. Water Works, Provincetown, Mass.	Sept. 8, 1897
Allen, Charles A., C. E. 44 Front St., Rooms 109-110, Worcester, Mass.	June 16, 1886
Allen, Charles F. Treasurer Water Company, Hyde Park, Mass.	June 16, 1886
Allis, Solon M., C. E. 43 James Street, Malden, Mass.	June 17, 1887
Amos, E. C. 51 Montreal Street Railway Bldg., Montreal, Can.	Nov. 14, 1900
Amyot, John A., M. B. Bacteriologist to the Provincial Board of Health of Ontario, 305 Joseph St., Toronto, Canada.	Nov. 14, 1900
Armstrong, S. G., C. E. Care F. W. Waldron, C. E., Amilanda, Upper Buitenkant St., Cape Town, South Africa.	Feb. 13, 1895
Anderson, J. M. 246 Pleasant St., Worcester, Mass.	Jan. 9, 1901
Andrews, Frank A. Assistant Supt. Pennichuck Water Works, Nashua, N. H.	Dec. 14, 1887
Appleton, Francis E. Paymaster Locks & Canals Co., Lowell, Mass.	Dec. 8, 1897
Babbidge, P. F. Supt. Water Works, Keene, N. H.	Feb. 12, 1890
Babcock, Stephen E. Water Works and Hydraulic Engineer, Little Falls, N. Y.	June 12, 1886

NAME.	Date of Election.
Bacot, R. C., Jr. Supt. Meter Dept., P. O. Box 221, Port Chester, N. Y.	Dec. 12, 1888
Badger, Frank S. Room 24, 35 Wall St., New York City.	June 10, 1896
Badger, Wm. E. Assistant Engineer, Locks & Canals Co., Lowell, Mass.	June 14, 1899
Bagnell, Richard W. Supt. Water Works, Plymouth, Mass.	Dec. 21, 1882
Bailey, E. W. City Engineer, Somerville, Mass.	Dec. 11, 1895
Bailey, Frank S. State Board of Health, State House, Boston, Mass.	Sept. 8, 1897
Bailey, George I. Supt. Bureau of Water, 300 Western Avenue, Albany, N. Y.	Dec. 14, 1892
Baldwin, Charles H. 159 Franklin St., Boston, Mass.	June 17, 1887
Baldwin, Richard Proprietor Water Works, Terryville, Conn.	June 10, 1891
Bancroft, Lewis M. Supt. Water Works, Reading, Mass.	Jan. 8, 1890
Barbour, Frank A., C. E. 1120 Tremont Building, Boston, Mass.	Jan. 10, 1894
Barnes, Roland D., C. E. 23 Spring Street, Malden, Mass.	June 14, 1899
Barrett, Albert P. Woburn, Mass.	March 12, 1890
Barrus, George H. Consulting Steam Engineer, 12-20 Pemberton Bldg., Pemberton Sq., Boston, Mass.	Jan. 14, 1891
Bartlett, Charles H., C. E. 9 Concord Square, Boston, Mass.	Feb. 8, 1893
Bartlett, R. S. Supt. Water Works, Norwich, Conn.	Jan. 13, 1897
Bassett, Carroll Ph. Treasurer Water Co., Summit, N. J.	June 13, 1889

NAME.	Date of Election.
Bassett, Geo. B., C. E. 363 Washington St., Buffalo, N. Y.	Sept. 10, 1897
Batchelder, George W. Water Registrar, Worcester, Mass.	June 14, 1899
Batcheller, Francis Water Commissioner, No. Brookfield, Mass.	Jan. 10, 1894
Bates, Oren B. Clinton, Mass.	Sept. 11, 1895
Bates, Hon. Theodore C. 29 Harvard St., Worcester, Mass.	Jan. 10, 1894
Battles, James M. 120 Marginal St., cor. Cottage St., East Boston, Mass.	June 21, 1882
Beals, Joseph E. Supt. Water Works, Middleboro, Mass.	June 16, 1886
Beasom, C. B., C. E. 248 Tremont St., Newton, Mass.	Dec. 12, 1894
Bennett, Thomas H. Supt. Water Works, Oswego, N. Y.	March 14, 1900
Benzenberg, G. H. Milwaukee, Wis.	June 9, 1892
Berkey, John A. Pres. Electric & Water Company, Little Falls, Minn.	Feb. 8, 1893
Bettes, Charles R. Chief Engineer, Queen's County Water Co., Far Rockaway, N. Y.	Dec. 9, 1896
Bigelow, James F. City Engineer, Marlboro, Mass.	Sept. 11, 1895
Birkinbine, Henry Hydraulic Engineer, 124 East Market Street, York, Pa.	June 17, 1887
Bisbee, Forrest E. Supt. Water Works, Auburn, Maine.	Sept. 11, 1895
Bishop, George H., C. E. 129 Main St., Middletown, Conn.	June 16, 1886
Bishop, Watson L. Supt. Water Works, Dartmouth, N. S.	March 8, 1893

NAME.	Date of Election.
Blackmer, James W., 2d Supt. Water Works, Beverly, Mass.	March 8, 1899
Bliss, Gerald M., C. E. 393 Warren Ave., Chicago, Ill.	Feb. 12, 1896
Blossom, William L., C. E. 355 Washington St., Brookline, Mass.	Dec. 13, 1893
Boggs, Edward M. Consulting, Civil and Hydraulic Engineer, 534 Stimpson Block, Los Angeles, Cal.	Dec. 11, 1889
Bowers, George City Engineer, Lowell, Mass.	March 9, 1892
Brackett, Dexter Engineer Distribution Dept., Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	April 21, 1885
Bradley, R. H. Supt. Water Works, Le Sueur, Minn.	Dec. 14, 1892
Brinsmade, Daniel S. President and Engineer Ousatonic Water Co. Birmingham, Ct.	Sept. 19, 1883
Broatch, J. C. Supt. Water Works, Middletown, Conn.	April 21, 1885
Brooks, Edwin C. Supt. Water Works, Cambridge, Mass.	Feb. 10, 1897
Brooks, Fred 31 Milk Street, Boston, Mass.	Feb. 8, 1899
Brown, A. W. F. Water Registrar, Fitchburg, Mass.	June 17, 1887
Brown, Edward H. Supt. and Treas. Nevada County N. G. R. R. Grass Valley, Cal.	June 16, 1886
Brown, J. Henry 3 Tremont St., Charlestown, Mass.	Sept. 19, 1883
Brown, Walter I. Water Registrar, Bangor, Me.	June 11, 1896
Brownell, Ernest H., C. E. Brownell Block, 107 Westminster St., Providence, R. I.	Jan. 11, 1893
Bryant, C. B. City Engineer, Martinville, Va.	June 10, 1886

NAME.	Date of Election.
Bucknam, George A. P. Supt. Water Works, Norwood, Mass.	June 10, 1891
Burke, James E. Sec'y, Treas., and Supt. Princeton Water Co., Princeton, N. J.	Sept. 11, 1895
Burley, Harry B. 31 Milk Street, Room 55, Boston, Mass.	Dec. 14, 1892
Burnham, Albert S. Supt. Water Company, Revere, Mass.	June 13, 1888
Burnie, James Supt. Water Company, Biddeford, Me.	June 11, 1890
Burns, James Lynn, Mass.	Sept. 13, 1899
Burns, Clinton S. 409 Postal-Telegraph Bldg., Kansas City, Mo.	Dec. 12, 1900
Burr, William H. Prof. of Civil Engineering, Columbia University, and Consulting Engineer, New York City.	Feb. 16, 1894
Burse, A. H. Supt. Water Works, Pittsfield, Me.	Sept. 16, 1898
Bush, Edward W., C. E. Ætna Life Building, Hartford, Conn.	Feb. 13, 1895
Butler, J. Allen Supt. Portland Water Company, Portland, Conn.	June 10, 1891
Cairns, R. A. City Engineer, Waterbury, Conn.	Feb. 13, 1895
Card, Huber D. City Engineer, Willimantic, Conn.	Jan. 8, 1896
Carpenter, L. Z. Attleboro, Mass.	Dec. 13, 1899
Carroll, Fred B. Rumford Falls, Me.	Dec. 12, 1888
Cassell, George Supt. Water Works, Chelsea, Mass.	March 8, 1899

NAME.	Date of Election.
Caulfield, John Sec'y Water Works, St. Paul, Minn.	Dec. 8, 1897
Cavanagh, John T. Quincy, Mass.	Feb. 8, 1893
Chace, George F. Supt. Water Works, Taunton, Mass.	June 13, 1888
Chadbourne, E. J. Supt. Water Company, Wakefield, Mass.	June 18, 1885
Chairman of Water Commission. Watertown, Mass.	Feb. 14, 1900
Chandler, Charles E. City Engineer, 161 Main St., Norwich, Conn.	June 17, 1887
Chandler, Prof. Charles F. 51 East 54th St., New York City.	Dec. 12, 1888
Chapin, G. L. Water Commissioner, Lincoln, Mass.	March 10, 1897
Chapman, Benjamin R. Assistant Engineer, Brockton, Mass.	Feb. 9, 1898
Chase, John C. Chief Engineer Water Works Company, Derry, N. H.	June 19, 1884
Clapton, William Supt. Water Company, Newtown, N. Y.	Sept. 11, 1895
Clapp, Sidney K. 1 Ashburton Place, Boston, Mass.	Jan. 10, 1900
Clark, D. W. President Water Company, Portland, Me.	June 12, 1890
Clark, S. Frederic Water Commissioner, North Billerica, Mass.	March 8, 1899
Clark, Frederick W. Clerk Chestnut Hill Reservoir, Metropolitan Water Works, Brighton, Mass.	Jan. 11, 1893
Clark, Harry W. Chemist, Mass. State Board of Health, State House, Boston, Mass.	March 14, 1894
Clarke, E. W. Asst. Engineer, Rapid Transit R.R. Commission, 13 Astor Place, New York City.	Jan. 10, 1894

NAME.	Date of Election.
Cleveland, W. F. Sewer Commissioner, Brockton, Mass.	June 9, 1892
Cochran, Robert L. Supt. Water Works, Nahant, Mass.	June 16, 1886
Codd, William F. Supt. Water Company, Nantucket, Mass.	June 21, 1885
Coffin, Freeman C. Civil and Hydraulic Engineer, 53 State Street, Boston, Mass.	Feb. 13, 1889
Coggeshall, R. C. P. Supt. Water Works, New Bedford, Mass.	June 21, 1882
Cole, D. W. Box 696, Thomaston, Conn.	March 14, 1900
Cole, F. M. Meter Inspector, Brockton Water Works, Brockton, Mass.	Feb. 10, 1897
Collins, Lewis P. Lawrence, Mass.	Dec. 12, 1894
Colson, Charles D. Water Commissioner, Holyoke, Mass.	March 9, 1898
Connell, Michael A. Supt. Water Works, St. Hyacinthe, P. Q.	Dec. 13, 1893
Cook, Byron I. Supt. Water Works, Woonsocket, R. I.	March 13, 1889
Cook, Henry A. Supt. Water Works, Salem, Mass.	Feb. 10, 1892
Cram, Arthur N. Water Commissioner, Walpole, Mass.	March 11, 1896
Crandall, F. H. Supt. and Treas. Water Works, Burlington, Vt.	June 13, 1888
Crandall, George K. Civil Engineer, New London, Conn.	June 9, 1892
Crawford, J. W. Clerk Water Board, Lowell, Mass.	June 12, 1896
Crilly, P. F. Supt. Water Works, Woburn, Mass.	March 12, 1890

NAME.	Date of Election.
Croes, J. J. R., C. E. 68 Broad Street, Morris Building, N. Y. City.	June 17, 1887
Crowell, George E. President Water Works, Brattleboro, Vt.	June 15, 1893
Crosby, Everett U. 54 William Street, New York City.	March 4, 1900
Cuddeback, Allan W. Asst. Engineer Passaic Water Company, 109 Washington St., Paterson, N. J.	Jan. 10, 1900
Curtis, George D. 75 Tonawanda St., Dorchester, Mass.	Sept. 19, 1900
Cushing, Lucas Box 108, Mansfield, Mass.	Dec. 12, 1888
Daboll, L. E., C. E. New London, Conn.	Jan. 10, 1894
Danforth, John L. Gen. Supt. Spring Water Company, Kane, Pa.	Sept. 10, 1897
Davis, F. A. W. Vice Pres. and Treas. Water Co., Indianapolis, Ind.	June 17, 1887
Davis, Henry L. Supt. Water Works, Wallingford, Conn.	Jan. 12, 1898
Davis, J. M. Rutland, Vt.	Sept. 13, 1895
Davis, William E. Supt. Water Works, Sherburne, N. Y.	Dec. 11, 1889
Davison, George S. Sec. and Gen. Manager Monongahela Street Railway Co., 512 Smithfield St., Pittsburg, Pa.	June 15, 1894
Dean, Arthur W. City Engineer, Nashua, N. H.	March 8, 1899
Dean, Francis W. Mechanical Engineer, 53 State St., Boston, Mass.	June 11, 1890
Dean, Seth, C. E. Glenwood, Iowa.	Dec. 12, 1888
Dean, William H. Water Analyst, Wilkesbarre, Pa.	Sept. 10, 1898

NAME.	Date of Election.
DeBerard, Wilford W. 116 Pembroke St., Boston, Mass.	Sept. 19, 1900
Decker, J. H. Room 37, Municipal Building, Brooklyn, N. Y.	June 18, 1885
Denman, A. N. Des Moines, Iowa.	June 16, 1886
Denton, J. E. Professor of Experimental Mechanics, Stevens Institute, Hoboken, N. J.	Dec. 11, 1889
Diven, J. M. Supt. Water Co., Elmira, N. Y.	June 16, 1886
Doane, A. O. Engineering Department, Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	Jan. 8, 1896
Doran, Hugh F. Supt. Water Works, Port Huron, Mich.	June 9, 1892
Downey, Wm. 49 Wellington St., Worcester, Mass.	June 14, 1899
Dotten, William T. Supt. Water Works, Winchester, Mass.	June 21, 1882.
Drake, Albert B., C. E. 164 William Street, New Bedford, Mass.	April 21, 1885
Drake, B. Frank Water Commissioner, Lakeport, N. H.	June 16, 1886
Drake, Charles E., C. E. New Bedford, Mass.	Jan. 8, 1890
Drown, Thomas M. President Lehigh University, So. Bethlehem, Penn.	June 13, 1888
Dunbar, E. L. Supt. Water Works, Bay City, Mich.	June 9, 1892
Dyer, Eben R. Supt. of Distribution, Portland, Me.	June 11, 1890
Eardley, B. A. Supt. Pacific Improvement Co. Water Works, Pacific Grove, Monterey County, Cal.	June 15, 1893
Eastman, Henry E. Supt. Water Works, Westport, N. Y.	Sept. 11, 1895

NAME.	Date of Election.
Eddy, Harrison P. Supt. Sewer Department, City Hall, Worcester, Mass.	June 15, 1894
Eglee, Charles H. Hydraulic Engineer, 17 Central Street, Boston, Mass.	June 13, 1889
Eldredge, Edward D. Manager Onset Water Co., 49 Monmouth St., Brookline, Mass.	Feb. 14, 1900
Ellis, George A. Civil Engineer, 158 Sherman St., Springfield, Mass.	June 21, 1883
Ellis, John W. Civil Engineer, Woonsocket, R. I.	Dec. 11, 1889
Ellsworth, Emory A. Civil and Hydraulic Engineer, Holyoke, Mass.	June 10, 1896
Ervin, John Sec'y and Treasurer Middleton Water Supply Co., Bridgeton, N. S.	June 9, 1892
Esterbrook, Arthur F. Water Commissioner, Leicester, Mass.	Sept. 10, 1897
Evans, George E. Civil Engineer, 95 Milk St., Boston, Mass.	Feb. 14, 1888
Evans, Myron Edward Civil Engineer, 20 Nassau St., New York City.	June 13, 1900
Ewell, William Walter Supt. Water Works, Quincy, Mass.	March 9, 1898
Ewing, William B. Civil Engineer, La Grange, Ill.	Dec. 13, 1899
Fairbanks, J. H. Chairman Water Commissioners, Winchendon, Mass.	March 11, 1896
Fales, Frank L. Asst. Engineer, Engineering Dept., Board of Trustees, Commissioners Water Works, Cincinnati, Ohio.	Dec. 13, 1893
Fanning, John T. Consulting Engineer, Kasota Block, Minneapolis, Minn.	April 21, 1885

NAME.	Date of Election.
Farnham, Elmer E. Supt. Water Works, Box 109, Sharon, Mass.	Dec. 11, 1889
Farnum, Loring N. Civil and Hydraulic Engineer, 53 State St., Boston, Mass.	Dec. 13, 1893
Fels, August Water Commissioner, Lowell, Mass.	Sept. 13, 1899
Felton, B. R. Civil Engineer, Tremont Bldg., Boston, Mass.	June 9, 1892
Felton, Charles R. City Engineer, City Hall, Brockton, Mass.	Feb. 16, 1894
Ferguson, John N. Asst. Engineer, Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	Dec. 14, 1898
Fifield, John W. D. Water Commissioner, North Brookfield, Mass.	June 15, 1894
Fish, J. B. Superintendent Water Works, Scranton, Pa.	Sept. 11, 1895
Fitch, Jasper A. Supt. Water Company, Manchester, Conn.	June 12, 1890
FitzGerald, Desmond Engineer Sudbury Dept. Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	April 21, 1885
Flinn, Richard J., M. E. West Roxbury Station, Boston, Mass.	Sept. 11, 1895
Fobes, A. A. Engineer Board of Public Works, Pittsfield, Mass.	Feb. 13, 1895
Folwell, A. Prescott Professor of Sanitary and Hydraulic Engineering, Lafayette College, Easton, Pa.	June 15, 1893
Forbes, Fred B. 502 State House, Boston, Mass.	June 14, 1899
Forbes, F. F. Supt. Water Works, Brookline, Mass.	Jan. 29, 1885
Forbes, Murray Manager Westmoreland Water Co., Greensburgh, Penn.	Feb. 11, 1891

NAME.	Date of Election.
Forbes, Z. R. Water Registrar, Brookline, Mass.	Jan. 8, 1890
Foss, William E. Engineers' Dept., Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	March 8, 1893
Foster, Joel Supt. Water Works, Montpelier, Vt.	Sept. 13, 1895
Foye, Andrew E., C. E. Acting Chief Engineer, Dept. of Highways and Viaducts, Greater New York, 21 Park Row, New York City.	Dec. 12, 1894
Freeman, John R. Pres. Factory Insurance Co's, Providence, R. I.	Dec. 12, 1888
French, D. W. Supt. Hackensack Water Co., Box 98, Weehawken, N. J.	June 9, 1892
French, Edward V. Insurance Inspector, 31 Milk St., Boston, Mass.	Sept. 10, 1897
French, Frank Baldwin Engineer and Supt. Board of Public Works, Woburn, Mass.	Sept. 16, 1898
Fteley, Alphonse 14 West 131st Street, New York City.	June 18, 1885
Fuller, Andrew D. 15 Lawrence St., Wakefield, Mass.	Dec. 15, 1899
Fuller, Frank E. P. O. Box 775, West Newton, Mass.	March 14, 1900
Fuller, Frank L. Civil Engineer, 12 Pearl St., Boston, Mass.	June 16, 1886
Fuller, George W. 220 Broadway, New York City.	March 8, 1893
Gage, Stephen DeM. Biologist Mass. State Board of Health.	Jan. 10, 1900
Gamwell, J. H. Treasurer, Water Company, Palmer, Mass.	June 17, 1887
Gardner, L. H. Supt. Water Works Co., New Orleans, La.	June 18, 1885

NAME.	Date of Election.
Gear, Col. A. S. 136 West Broadway, New York City.	Sept. 10, 1897
Geer, Harvey M. Civil Engineer, Balston Spa, N. Y.	Sept. 10, 1897
Gerhard, William Paul Civil Engineer, and Consulting Engineer for Sanitary Works, 36 Union Square, East, New York City.	Dec. 12, 1888
Gerrish, William B. Supt. and Engineer Water Works, Oberlin, O.	Dec. 14, 1892
Gerry, L. L. Civil Engineer, Stoneham, Mass.	Jan. 29, 1885
Gibbs, Harry F. 106 Pond St., Natick, Mass.	Jan. 11, 1899
Gilbert, Julius C. Water Registrar and Treas. Water Works, Whitman, Mass.	June 15, 1894
Gilderson, D. H. Supt. Water Works, Haverhill, Mass.	Sept. 11, 1895
Gleason, Fred B. Inspector, Marlboro, Mass.	Sept. 13, 1895
Gleason, J. F. Foreman of Construction for Water Works, Quincy, Mass.	Feb. 9, 1898
Gleason, T. C. Supt. Water Works, Ware, Mass.	June 15, 1894
Glover, Albert S. Tremont Temple Building, Boston, Mass.	June 21, 1882
Goldthwait, W. J. Marblehead, Mass.	June 11, 1890
Goodnough, X. H. Engineer, State Board of Health, Room 140, State House, Boston, Mass.	Jan. 14, 1891
Gould, Amos A. Water Commissioner, Leicester, Mass.	March 11, 1896
Gould, J. A. Chief Engineer, Brookline and Dorchester Gas Light Companies.	June 14, 1888

NAME.	Date of Election.
Gow, Frederick W. Supt. Water Works, Medford, Mass.	June 11, 1890
Gowing, E. H., C. E. 22 Pemberton Square, Boston, Mass.	April 21, 1885
Graham, James W. Supt. Meter Dept., Portland Water Co., Portland, Me.	Sept. 13, 1895
Greaney, Thomas F. Water Commissioner, Holyoke, Mass.	March 9, 1898
Greene, S. C. Chairman Water Board, St. Albans, Vt.	Sept. 11, 1895
Greetham, H. W. Local Manager Orlando Water & Sewerage Co., Orlando, Florida.	June 13, 1889
Griffin, J. William Care N. Y. & N. J. Water Co., Arlington, N. J.	Dec. 12, 1900
Groce, William R. Supt. Water Works, Rockland, Mass.	Dec. 12, 1888
Gubelman, F. J., C. E. 792 Montgomery St., Jersey City, N. J.	March 11, 1896
Haberstroh, Charles E. Assistant Supt. Metropolitan Water Works, South Framingham, Mass.	Jan. 10, 1900
Haines, William T. Waterville, Me.	Jan. 11, 1899
Hale, Richard A. Principal Assistant Engineer, Essex Company, Lawrence, Mass.	Feb. 14, 1888
Hall, Frank E. Care Sumner & Goodwin Co., 289 Congress St., Boston, Mass.	June 21, 1882
Hall, Hon. John O. 1230 Hancock St., Quincy, Mass.	Dec. 12, 1900
Hammatt, E. A. W. Civil Engineer, 53 State St., Boston, Mass.	June 17, 1887
Hammond, J. C., Jr. Secretary and Treasurer, Rockville Water & Aqueduct Co., Rockville, Conn.	Jan. 11, 1888

NAME.	Date of Election.
Hancock, Joseph C. Supt. Water Works, Springfield, Mass.	June 21, 1882
Hapgood, Lyman P. Supt. Athol Water Co., Athol, Mass.	Nov. 14, 1900
Hardy, J. D. Supt. Water Works, Holyoke, Mass.	March 9, 1898
Haring, James S. Civil Engineer, Crafton, Alleghany Co., Pa.	June 9, 1892
Harlow, James H. President Pennsylvania Water Co., Wilkinsburg, Pa. Address Station D, Pittsburg, Pa.	Sept. 10, 1897
Harrington, Geo. W. Wakefield, Mass.	Dec. 10, 1890
Harris, D. A. Supt. Water Works, New Britain, Conn.	March 14, 1888
Hart, Edward W. General Manager Water Works, Council Bluffs, Iowa.	June 10, 1891
Hartwell, David A. City Engineer, Fitchburg, Mass.	Feb. 16, 1894
Hastings, L. M. City Engineer, Cambridge, Mass.	June 13, 1889
Hastings, V. C. Supt. Water Works, Concord, N. H.	June 10, 1886
Hatch, Arthur Elliott Mechanical Engineer, Bay State Dredging Co., 59 High St., Boston, Mass.	Dec. 11, 1895
Hatch, S. S. Water Commissioner, South Norwalk, Conn.	June 11, 1896
Hathaway, A. R. Water Registrar, Springfield, Mass.	June 10, 1891
Hathaway, James H. Water Registrar, New Bedford, Mass.	June 21, 1882
Hawes, Louis E. Civil and Hydraulic Engineer, Tremont Building, Boston, Mass.	Dec. 12, 1888

NAME.	Date of Election.
Hawes, William B. Water Commissioner, Fall River, Mass.	June 15, 1894
Hawks, William E. Pres. and Treas. Water Co., Bennington, Vt.	Dec. 12, 1894
Hawley, W. C. Supt. Water Dept., Atlantic City, N. J.	Sept. 8, 1897
Hayes, Ansel G. Asst. Supt. Water Works, Box 323, Middleboro, Mass.	June 13, 1889
Hazard, T. G., Jr. Civil Engineer, Narragansett Pier, R. I.	June 15, 1894
Hazen, Allen Civil Engineer, 220 Broadway, New York, N.Y.	June 9, 1892
Heald, Simpson C. Civil Engineer, 48 Congress St., Boston, Mass.	April 21, 1885
Heermans, Harry C. Supt. Water Works, Corning, N. Y.	June 16, 1886
Henderson, Wilson Supt. Water Co., Peterborough, Ontario, Can.	June 17, 1887
Hering, Rudolph Hydraulic, Civil and Sanitary Engineer, 100 William St., New York City.	June 17, 1887
Herschel, Clemens Hydraulic Engineer, 2 Wall Street, Room 68, New York City.	Feb. 10, 1892
Hicks, R. S. 75 Warren St., New York, N. Y.	June 17, 1887
Higgins, James H. Supt. Meter Dept., City Hall, Providence, R. I.	Feb. 8, 1893
Hill, Hibbert Winslow Director Bact. Laboratory Boston Board of Health, 607 Sudbury Building, Sudbury St., Boston.	Sept. 10, 1897
Hill, William R. Chief Engineer Croton Aqueduct Commission, 280 Broadway, New York City.	June 9, 1892

NAME.	Date of Election.
Hodgdon, Frank W. Engineer Mass. Harbor and Land Commission, 131 State House, Boston, Mass.	June 12, 1895
Hodgdon, John S. Wellington, Mass.	June 15, 1894
Holden, Horace G. Supt. Pennichuck Water Works, Nashua, N. H.	June 21, 1882
Hollis, Frederick S. Instructor in Chemistry, Yale Medical School, New Haven, Conn.	Dec. 8, 1897
Holman, M. L. Consulting Engineer, 3744 Finney Avenue, St. Louis, Mo.	June 16, 1886
Hook, G. S. Civil Engineer. 705 Union St., Schenectady, N. Y.	Sept. 13, 1899
Hopkins, Charles C., C. E. Rome, N. Y.	March 10, 1897
Hotchins, Geo. A. Supt. Water Works, Rochester. N. Y.	June 13, 1900
Howard, John L. Assistant Engineer Met. Water Board. No. 1 Ashburton Place, Boston, Mass.	Jan. 10, 1900
Hubbard, Winfred D. Supt. Water Works, Concord. Mass.	Sept. 19, 1900
Hubbell, Clarence W. Water Office, Detroit, Mich.	Sept. 13, 1899
Hunking, Arthur W. 374 Stevens St., Lowell. Mass.	June 11, 1890
Hunter, Henry G. Civil Engineer, Quincy, Mass.	March 13, 1895
Huntington, James A. Water Registrar, Haverhill. Mass.	Dec. 9, 1891
Hyde, Horatio N. Newton ve. Mass.	June 21, 1882
Illig, Frank J. Supt. Water Dept., Buffalo. N. Y.	Sept. 13, 1899

NAME.	Date of Election.
Jackson, Daniel D. Chemist Division of Water Supply, Mt. Prospect Laboratory, Brooklyn, N. Y.	March 14, 1894
Jackson, William City Engineer, City Hall, Boston, Mass.	June 11, 1890
Johnson, H. R. Water Commissioner, Reading, Mass.	Dec. 14, 1898
Johnson, William S. Assistant Engineer State Board of Health, Room 140, State House, Boston, Mass.	Jan. 10, 1894
Jones, A. J. New Brunswick, N. J.	Dec. 14, 1887
Jones, James A. Water Registrar, Stoneham, Mass.	March 14, 1894
Jones, R. A. Civil Engineer, Spokane, Washington.	June 17, 1887
Jordan, John N. Supt. Water Works, Malden, Mass.	June 12, 1896
Judkins, Fred G. Franklin Falls, N. H.	Feb. 14, 1899
Kay, J. William Supt. Water Works, 75 Congress St., Milford, Mass.	Jan. 9, 1901
Kent, E. W. Civil Engineer, Woonsocket, R. I.	Feb. 8, 1893
Kent, Willard Manager Water Company, Narragansett Pier, R. I.	April 21, 1885
Kieran, Patrick Supt. Water Works, Fall River, Mass.	June 16, 1886
Kilbourn, Wm. A. Secretary (Lancaster) Water Commissioners, South Lancaster, Mass.	Dec. 13, 1899
Killam, James W. Metropolitan Water Board, Reading, Mass.	Dec. 13, 1899
Kimball, Frank C. Supt. Knoxville Water Co., 619 South Gay St., Knoxville, Tenn.	Feb. 12, 1896

NAME.	Date of Election
Kimball, George A. Chief Engineer Elevated Lines Boston Elevated Railway, Member Metropolitan Sewerage Board, 101 Milk St., Boston, Mass.	June 17, 1887
Kimball, William L. 241 Columbus Avenue, Boston, Mass.	Dec. 13, 1899
Kingman, Horace Supt. Water Works, Brockton, Mass.	June 15, 1893
Kinnicutt, Leonard P. 77 Elm Street, Worcester, Mass.	Feb. 8, 1893
Kinsey, Warren R. Civil Engineer, 108 Fulton Street, New York City.	Sept. 11, 1895
Knapp, Louis H. Engineer Buffalo Water Works, 280 Linwood Avenue, Buffalo, N. Y.	June 17, 1887
Knight, Charles William, C. E. Rome, N. Y.	March 10, 1897
Knowlton, Charles F Commissioner of Public Works, Quincy, Mass.	Sept. 19, 1900
Knowles, Morris Assistant Engineer in charge of Testing Station, Spring Garden Water Works, Philadelphia, Pa.	June 12, 1895
Koch, Harry G. Supt. Castle Creek Water Company, Aspen, Col.	Dec. 11, 1889
Kuehn, Jacob L. Supt. Water Co., York, Pa.	June 9, 1892
Kuichling, Emil Consulting Engineer, Rochester, N. Y.	Sept. 10, 1897
Laforest, J. O. Alfred Chief Engineer Laurentian Water & Power Co., La Presse Bldg., Montreal, Quebec.	Dec. 14, 1892
Laing, W. H. Secretary and Supt., Racine Water Co., Racine, Wis.	June 13, 1889
Lansing, Edward T. E. Civil Engineer, Little Falls, N. Y.	June 13, 1889

NAME.	Date of Election
Larned, Edward S. Metropolitan Water Supply, South Framingham, Mass.	Jan. 10, 1900
Lautz, Adolphe W. Secretary Water Co., Pekin, Ill.	Sept. 16, 1898
Lawton, Perry Civil Engineer, Savings Bank Building, Quincy, Mass.	Feb. 16, 1894
Lea, R. S. Assistant Professor of Civil Engineering, McGill University, Montreal, P. Q.	June 15, 1893
Learned, Wilbur F. Civil Engineer, Watertown, Mass.	April 21, 1885
Linsley, J. H. 196 Main St., Burlington, Vt.	March 8, 1899
Livermore, N. B. 320 Sansom St., San Francisco, Cal.	Feb. 14, 1900
Locke, James W. Foreman, Brockton, Mass.	Jan. 9, 1895
Lord, Harry A. Supt. Water Works, Ogdensburg, N. Y.	Sept. 8, 1897
Loretz, Arthur J. L. Mechanical Engineer, 150 Nassau Street, New York City.	Dec. 9, 1896
Lovell, Thomas C. Supt. Water Works, 104 River Street, Fitchburg, Mass.	June 21, 1882
Loweth, Charles F. 94 East 4th Street, St. Paul, Minn.	Jan. 9, 1901
Luce, Francis H. Supt. Woodhaven Water Supply Co., Woodhaven, N. Y.	June 12, 1896
Ludlow, J. L. 434 Summit Street, Winston, N. C.	Feb. 14, 1900
Lunt, Cyrus M. Supt. Water Works, Lewiston, Me.	Dec. 9, 1896

NAME.	Date of Election.
Lusk, James L. Major Corps of Engineers, U. S. Army, Washington, D. C.	March 13, 1889
Luther, William J., C. E. Asst. Supt. Attleboro Gas Light Co., Attleboro. Mass.	June 15, 1893
MacMurray, J. C. President and General Manager Cherryvale (Kan.) Water Company, 33 Oak Ave., Worcester, Mass.	Dec. 9, 1896
Mann, Thomas W. Civil Engineer. Holyoke, Mass.	June 9, 1892
Manning, George E. Civil Engineer, New London, Conn.	March 9, 1898
Marble, Arthur D. City Engineer, Lawrence, Mass.	Feb. 12, 1896
Marion, J. A. Civil Engineer, New York Life Building, Montreal. P. Q.	Dec. 13, 1893
Martin, A. E. Supt. Water Company. South Framingham, Mass.	April 21, 1885
Martin, Cyrus B. Treas. Water Co., Norwich, N. Y.	June 17, 1887
Marvell, Edward I. Civil Engineer, 81 Bedford St., Fall River, Mass.	Jan. 13, 1897
Mason, William P. Professor of Chemistry, Rensselaer Polytechnic Institute, Troy, N. Y.	Dec. 11, 1895
Mather, Nelson E. Supt. Water Works, Clinton, Mass.	Sept. 19, 1900
Mattice, Asa M. Chief Engineer Westinghouse Electric and Mfg. Co., East Pittsburg, Pa.	June 15, 1894
Maybury, William E. Supt. Water Works, Braintree, Mass.	Jan. 9, 1901
Maxcy, Josiah S. Treas. Madison Water Company, Gardiner, Me.	Dec. 14, 1887

NAME.	Date of Election.
McCarthy, Daniel B. Supt. Water Works Co., Waterford, N. Y.	Sept. 11, 1895
McClintock, W. E. Member of Massachusetts Highway Commission, 15 Court Square, Boston, Mass.	June 17, 1887
McClure, Frederick A. City Engineer, Worcester, Mass.	June 15, 1894
McConnell, B. D. Civil Engineer, 185 St. James St., Montreal, P. Q.	June 12, 1890
McDonald, M. L. Supt. and Secretary Water Works, Santa Rosa, Cal.	Sept. 11, 1895
McIntosh, H. M. City Engineer, Burlington, Vt.	Sept. 11, 1895
McKenzie, Theodore H. Manager Water Works, Southington, Conn.	June 12, 1890
McKenzie, Thomas Superintendent Water Works, Box 712, Westerly, N. Y.	Dec. 12, 1894
McMillen, Norman A. Supt. Water Works, North Billerica, Mass.	June 13, 1900
McNally, William 64 Chestnut Street, Marlboro, Mass.	June 11, 1890
Mead, Daniel W. 605 First National Bank Building, Chicago, Ill.	Sept. 19, 1900
Merrill, Frank E. Water Commissioner and Supt. Water Works, Somerville, Mass.	Dec. 9, 1896
Merritt, D. S. Engineer and Supt. Water Works, Tarrytown, N. Y.	Dec. 13, 1893
Metcalf, Leonard Civil Engineer, 14 Beacon St., Boston, Mass.	Feb. 10, 1897
Metcalfe, Henry President Water Board, Cold Spring, N. Y.	June 10, 1896

NAME.	Date of Election.
Miller, A. M. Lieut.-Col. Corps of Engineers, U. S. A., 2728 Pennsylvania Avenue, Washington, D. C.	Nov. 14, 1900
Miller, John F. Assistant Sec'y Westinghouse Air Brake Co., East Pittsburg, Pa.	June 10, 1896
Miller, P. Schuyler 108 Park Place, Brooklyn, N. Y.	Jan. 10, 1900
Mills, Frank H. City Engineer, Woonsocket, R. I.	Jan. 14, 1891
Mirick, George Langdon Civil Engineer, 104 Porter St., Malden, Mass.	June 15, 1893
Molis, William Supt. Water Works Co., Muscatine, Iowa.	June 17, 1887
Mullhall, John F. J. Treas. Portland (Ct.) Water Co., 11 Beacon St., Boston. Mass.	Nov. 14, 1900
Murdoch, William Supt. Water Works. St. John, N. B.	Jan. 10, 1900
Myers, J. H., Jr. Asst. Engineer N. Y. Rapid Transit R. R. Commission, 90 Pierrepont St., Brooklyn, N. Y.	Sept. 11, 1895
Nash, H. A., Jr. Civil Engineer, Weymouth Heights, Mass.	March 13, 1895
Naylor, Thomas Supt. Water Works, Maynard. Mass.	Feb. 16, 1894
Nettleton, Charles H. Treasurer and Supt. Water Co., Birmingham, Conn.	June 16, 1886
Newhall, John B. 184 Bay Street, Stapleton, Staten Island.	Dec. 14, 1892
Nichols, Thomas P. Member Water Board, 11 Prospect St., Lynn, Mass.	Jan. 10, 1894
Northrop, Frank L. P. O. Box 1566, Saco, Me.	June 15. 1893

NAME.	Date of Election.
Nuebling, Emil L. Engineer and Supt. Water Dept., Reading, Penn.	Feb. 12, 1896
Nye, George H. Civil Engineer. New Bedford, Mass.	March 11, 1891
Nye, Joseph K. President Water Company, Fairhaven, Mass.	March 8, 1893
O'Connell, P. D. Supt. Water Works, Somersworth, N. H.	Sept. 16, 1898
Paine, C. W. Constructing Engineer on Extension of Butte City Water Works, Lewisohn Building, Butte, Mont.	Dec. 12, 1888
Parker, Charles B., Asst. Supt. Water Works, Cambridge, Mass.	Jan. 9, 1901
Parker, Horatio N. Biologist Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	March 10, 1897
Parks, Charles F. Civil Engineer, 11 Beacon St., Boston, Mass.	Dec. 11, 1889
Parsons, Frank N Clerk Water Board, Franklin, N. H.	March 9, 1892
Patch, Walter Woodbury Civil Engineer, Eastern Avenue. So. Framingham, Mass.	June 12, 1895
Paulison, Washington Supt. Acquackanonk Water Co., Passaic, N. J.	Sept. 16, 1898
Payson, E. R. Secretary Portland Water Co., Portland, Me.	June 13, 1900
Pease, A. G. Water Commissioner, Spencer, Mass.	June 16, 1886
Peene, Edward L. Supt. Water Works, Yonkers, N. Y.	Sept. 16, 1898
Peirce, Charles E. Supt. East Providence Water Co., East Providence Centre, R. I.	Sept. 14, 1887
Perkins, John H. Supt. Watertown and Belmont Water Works, Watertown, Mass.	June 16, 1886

NAME.	Date of Election
Perry, Fred G. Pawtucket, R. I.	Feb. 13, 1895
Phillips, Edward Civil Engineer, No. 11 Broadway, N. Y.	Dec. 8, 1897
Pierce, Frank L. 464 Elm St., Richmond Hill, Queens County, N. Y.	Dec. 14, 1898
Pitman, Winthrop M. Treasurer North Conway Water and Improvement Co. Address 493 Centre Street, Jamaica Plain, Mass.	June 17, 1887
Pitney, Frederic V. Engineer, Morristown Aqueduct Co.. Morristown, N. J.	Feb. 16, 1894
Pittman, William General Manager Water Works, Box 305, Jerseyville, Ill.	Dec. 9, 1891
Pollard, William D. General Manager Water Co., Pottsville, Pa.	June 10, 1891
Porter, Dwight Professor of Hydraulic Engineering, Massachusetts Institute of Technology, Boston, Mass.	March 13, 1889
Potter, Alexander Civil and Sanitary Engineer, 137 Broadway, New York City.	March 14, 1894
Poussin, Ludovic de la Vallee Constructing Engineer, P. O. Box 1144, Montreal. P. Q.	June 15, 1894
Pratt, Charles W. Utica, N. Y.	June 11, 1890
Probst, C. O. Secretary State Board of Health, Columbus, Ohio.	Dec. 8, 1897
Putnam, J. B. Supt. Westboro Water and Sewer Depts., Westboro, Mass.	Sept. 10, 1897
Rawson, Waldo E. Supt. Water Works, Uxbridge, Mass.	June 9, 1892

NAME.	Date of Election.
Reed, D. A. Civil and Hydraulic Engineer, 312 Providence Building, Duluth, Minn.	Feb. 6, 1894
Reynolds, E. H. Brockton, Mass.	June 9, 1892
Rice, George S. Deputy Chief Engineer Rapid Transit Railroad Commissioners, 320 Broadway, New York City.	Dec. 14, 1892
Rice, James L. Supt. Water Co., Claremont, N. H.	June 15, 1894
Rice, L. Frederick Architect and Civil Engineer, 125 Milk St. Boston, Mass.	June 17, 1887
Richards, H. DeC. Manager Water Works, 123 Liberty Street, New York City.	June 10, 1896
Richards, Walter H. Supt. Water Works, New London, Conn.	Oct. 11, 1882
Richardson, Charles W. Water Commissioner, 8 High Street, Everett, Mass.	March 13, 1895
Richardson, T. F. Dept. Engineer Metropolitan Water Board, Clinton, Mass.	Feb. 10, 1897
Ridpath, J. W. Secretary and Manager Water Company, Jenkintown, Pa.	June 9, 1892
Ries, George J. Supt. Water Works, Weymouth Centre, Mass.	June 16, 1886
Riley, Charles E. Member Water Board, Brookline, Mass.	Sept. 13, 1899
Ringrose, J. W. New Britain, Conn.	Feb. 14, 1888
Robbins, F. H. Civil Engineer, 1 Ashburton Place, Boston, Mass.	Sept. 10, 1897

NAME.	Date of Election
Roberts, Vaughn M. Civil Engineer, 700-701 Lewis Block, Pittsburg, Pa.	Dec. 13, 1893
Robertson, George H. Supt. Water Works, Yarmouth, N. S.	June 9, 1892
Robertson, W. W. Water Registrar, Fall River, Mass.	June 17, 1887
Robinson, A. Supt. Water Works, Benicia, Cal.	June 11, 1896
Roden, Thomas Supt. Water Works, Arlington, Mass.	June 12, 1896
Rogers, Henry W. 62 Arlington St., Haverhill, Mass.	June 21, 1882
Rogers, Thomas H. Pumping Engineer, Pennichuck Water Works, Nashua, N. H.	Sept. 8, 1897
Rotch, William Civil Engineer, Room 742, Exchange Building, 53 State St., Boston, Mass.	June 16, 1886
Roullier, G. A. Supt. Water Works, Flushing, N. Y.	June 13, 1889
Royce, Harley E. Assistant Engineer, Brookline, Mass.	Jan. 9, 1895
Russell, A. N. Pres. Water Commissioners, Ilion, N. Y.	Sept. 13, 1899
Russell, Daniel Everett, Mass.	June 19, 1884
Salisbury, A. H. Supt. Water Works, Lawrence, Mass.	Jan. 11, 1888
Sanborn, Willard T. Supt. Water Works, 87 Portland St., Dover, N. H.	March 14, 1894
Sanders, George O. Pres. Water Works Co., Hudson, N. H.	Jan. 13, 1892
Sando, W. J. Manager Water Works Dept., International Steam Pump Co., Brooklyn, N. Y.	June 12, 1895

NAME.	Date of Election.
Saville, Caleb M. Engineering Dept. Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	March 8, 1893
Sawyer, Frederick W. Water Registrar, Milford, N. H.	Dec. 9, 1891
Sears, Walter H. 220 Sandwich St., Plymouth, Mass.	Sept. 13, 1899
Sealy, W. F. P. Supt. Water Works, Potsdam, N. Y.	Sept. 13, 1895
Sedgwick, William T. Professor of Biology, Massachusetts Institute of Technology, Boston, Mass.	Feb. 12, 1890
Sharples, Philip P. 22 Concord Avenue, Cambridge, Mass.	June 14, 1899
Shedd, Edward M. Inspector Water Works, Somerville, Mass.	Jan. 9, 1901
Shedd, Edward W. Civil Engineer, 146 Westminster St., Providence, R. I.	March 9, 1892
Shedd, J. Herbert Consulting Engineer, Providence, R. I.	June 13, 1888
Shepard, F. J. Treasurer Water Co., Derry, N. H.	June 15, 1893
Sherman, Charles W. Civil Engineer, Assistant Engineer Metropolitan Water Works, 1 Ashburton Place, Boston, Mass.	Sept. 10, 1897
Sherman, William B. Mechanical Engineer, Box 974, Providence, R. I.	Oct. 11, 1882
Sherrerd, Morris R. Engineer Water Dept., Newark, N. J.	March 10, 1897
Shippee, John D. Holliston, Mass.	Jan. 14, 1891
Shirreffs, Reuben Chief Engineer Virginia Electric Railway and Development Co., Richmond, Va.	March 12, 1890
Sinclair, Melville A. Supt. Water Works, Bangor, Me.	June 15, 1894

NAME.	Date of Election.
Smith, Herbert E. Professor of Chemistry, Yale Medical School, Chemist Conn. St. Board of Health, Address 430 George St., New Haven, Conn.	Dec. 14, 1892
Smith, H. O. Water Commissioner, Leicester, Mass.	June 15, 1894
Smith, John E. Supt. Water Works, Andover, Mass.	June 10, 1896
Smith, J. J. City Engineer, Grand Forks, N. D.	Nov. 14, 1900
Smith, J. Waldo Supt. Passaic Water Co., 109 Washington St., Paterson, N. J.	Dec. 13, 1893
Smith, Sidney Civil Engineer, 91 Maple St, West Roxbury, Mass.	June 12, 1895
Smith, Solon F. Supt. and Treas. Water Co., Grafton, Mass.	June 17, 1887
Snell, George H. Water Commissioner and Supt. Water Works, Attleboro, Mass.	Dec. 12, 1900
Snow, Edwin W. 14 Carleton Street, Somerville, Mass.	June 15, 1894
Soper, George A. 29 Broadway, New York City.	Jan. 12, 1898
Souther, Henry Water Commissioner, Hartford, Conn.	June 13, 1900
Sparks, H. T. Supt. Water Dept., Public Works Co., Bangor, Me., Address, Box 208, Brewer, Me.	June 15, 1894
Springfield, John F. Civil Engineer, 64 Summer Street, Rochester, N. H.	Jan. 13, 1892
St. Louis, J. A. Water Registrar, Marlborough, Mass.	Sept. 10, 1897
Stacy, George A. Supt. Water Works, Marlborough, Mass.	April 21, 1885
Starr, William W. Civil Engineer, 304 Court Exchange Building, Bridgeport, Conn.	Jan. 14, 1891

NAME.	Date of Election.
Stearns, Frederic P. Chief Engineer Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.	June 17, 1887
Stevenson, Harry W. 31 Waterford St., Lowell, Mass.	Sept. 21, 1900
Stoddard, S. G., Jr. Supt. and Engineer Bridgeport Hydraulic Co. 323 Water Street, Bridgeport, Conn.	June 9, 1892
Stone, Charles A. Electrical Engineer, 4 Postoffice Square, Boston, Mass.	June 15, 1894
Stubbs, J. H. With Metropolitan Sewerage Commission, 20 Pemberton Sq., Boston, Mass.	Sept. 13, 1899
Street, L. Lee 121 Stoughton St., Dorchester, Mass.	Jan. 10, 1900
Sullivan, John C. Holyoke, Mass.	June 15, 1893
Sullivan, J. J. Water Commissioner, Holyoke, Mass.	March 9, 1898
Sullivan, William F. City Engineer's office, Lowell, Mass.	Feb. 14, 1900
Sutherland, D. A. Supt. Water Works, Lynn, Mass.	Feb. 8, 1893
Swain, George F. Professor of Civil Engineering, Massachusetts Institute of Technology, Boston, Mass.	June 17, 1887
Swan, Joseph W. Assistant Clerk, Water Commissioners' office, Boston, Mass.	Feb. 11, 1891
Tabb, William B. Guam, P. I.	June 15, 1893
Taber, Robert W. Water Commissioner, New Bedford, Mass.	Sept. 16, 1898
Taylor, Charles N. Wellesley, Mass.	Feb. 13, 1901
Taylor, Edwin A. Constructing Engineer, 73 Tremont Street, Boston, Mass.	Dec. 14, 1892
Taylor, Frederick L. Engineer, Brookline Water Works, Brookline, Mass.	Feb. 13, 1895

NAME.	Date of Election.
Taylor, Lucian A. Civil Engineer and Contractor, 73 Tremont St., Boston, Mass.	June 19, 1884
Tenney, D. W. Methuen, Mass.	June 10, 1896
Tenney, Joseph G. Treas. and Supt. Water Works,. Leominster, Mass.	June 21, 1882
Thomas, Robert J. Supt. Water Works, Lowell, Mass.	June 9, 1892
Thomas, Harry L. Asst. Supt. Water Co., Hingham, Mass.	Dec. 14, 1898
Thomas, William H. Supt. Water Co., Hingham, Mass.	Dec. 14, 1887
Thomson, John Hydraulic Engineer, 253 Broadway, New York City.	June 9, 1892
Tighe, James L. Engineer Water Works, Holyoke, Mass.	March 9, 1898
Tingley, R. H. Civil Engineer, 75 Westminster St., Providence, R. I.	Feb. 8, 1893
Tinkham, S. Everett Assistant Engineer, Engineering Dept., City Hall, Boston, Mass.	Jan. 14, 1891
Tompkins, Charles H. Civil Engineer, 120 Liberty Street, New York City.	Dec. 11, 1889
Tower, D. N. Supt. Water Co., Cohasset, Mass.	June 17, 1887
Travis, George W. Supt. Water Works, Natick, Mass.	Dec. 13, 1899
Treman, E. M. Supt. and Secretary. Water Co.. Ithaca, N. Y.	June 11, 1890
Tribus, Louis L. Cons. Civil and Hydraulic Engineer. 84 Warren Street. New York City.	March 11, 1896
Turner, H. N. Manager Water Co., St. Johnsbury, Vt.	Dec. 11, 1895

NAME.	Date of Election.
Tuttle, Arthur S. Civil Engineer, Department Water Supply, 82d St., near 11th Ave., Brooklyn, N. Y.	March 14, 1894
Tubbs, J. Nelson General Inspector, Dept. of Public Works, State of New York, 207 Wilder Building, Rochester, N. Y.	June 11, 1890
Vallaincourt, J. A. Asst. Treas. Water Co., Berlin, N. H.	Sept. 13, 1899
Vaughn, W. H. Supt. Water Works, Wellesley Hills, Mass.	Dec. 11, 1889
Venner, John Chief Inspector Bureau of Water, Syracuse, N. Y.	Jan. 11, 1899
Wade, William W. Water Registrar, Woburn, Mass.	Dec. 8, 1897
Walker, Charles K. Supt. Water Works, Manchester, N. H.	June 21, 1882
Walker, John Civil Engineer, Newmarket, N. H.	Dec. 12, 1894
Wallace, E. L. Supt. Water Works, Franklin Falls, N. H.	Dec. 14, 1892
Warde, John S. Supt. Staten Island Water Supply Co., West New Brighton, Staten Island, N. Y.	June 15, 1894
Wardsworth, A. R. Civil Engineer, Farmington, Conn.	June 15, 1894
Warren, H. A. Supt. Water Works, St. Albans, Vt.	Dec. 14, 1892
Webster, F. P. Supt. Water Works Co., Lakeport, N. H.	Jan. 8, 1890
Welch, J. Alfred Taunton, Mass.	Feb. 13, 1895
Westcott, George P. Treasurer Portland Water Co., Portland, Me.	June 16, 1886
Weston, Robert S. Chemist and Bacteriologist, 14 Beacon St., Boston, Mass.	Sept. 8, 1897

NAME.	Date of Election.
Wheeler, Elbert Treasurer Water Company, Knoxville, Tenn., Address, 14 Beacon St., Boston, Mass.	Dec. 9, 1891
Wheeler, Warren B. Assistant City Engineer, Fitchburg, Mass.	Feb. 16, 1894
Wheeler, William Civil Engineer, 14 Beacon St., Boston, Mass.	Dec. 11, 1889
Whipple, George C. Mt. Prospect Laboratory, Flatbush Avenue and Eastern Parkway, Brooklyn, N. Y.	Feb. 8, 1893
Whitcomb, W. H. President Water Co., Norway, Me.	June 16, 1886
Whitham, Jay M. Mechanical Engineer, 607 Bullitt Building, Philadelphia, Pa.	Dec. 13, 1893
Whitman, Herbert T. Civil Engineer, 85 Devonshire Street, Boston, Mass.	Feb. 8, 1893
Whitney, John C. Water Commissioner, Newton, Mass.	June 17, 1887
Whittemore, W. P. Supt. Electric Light and Water Depts., No. Attleboro, Mass.	June 16, 1886
Whittier, Herbert F. 253 Jackson Street, Lawrence, Mass.	Jan. 11, 1888
Wigal, James P. Superintendent and Engineer Water Works, Henderson, Ky.	June 16, 1886
Wilcox, William C. Waltham, Mass.	June 21, 1882
Wilde, George E. Assistant Superintendent Metropolitan Water Works, Medford, Mass.	June 16, 1886
Wilder, Frederick W. Treasurer Aqueduct Company, Woodstock, Vt.	Dec. 12, 1888
Wilkins, Frank B. Supt. Water Works, Milford, N. H.	Feb. 14, 1900

NAME.	Date of Election.
Williams, Gardner S. Engineer in charge of Hydraulic Laboratory, and Prof. of Experimental Hydraulics, Cornell University, Ithaca, N. Y.	June 12, 1895
Williams, William F. City Engineer, New Bedford, Mass.	Feb. 16, 1894
Winslow, C.-E. A. Mass. Inst. of Technology, Boston, Mass.	Sept. 21, 1900
Winslow, Frederic I. Assistant Engineer, City Engineer's office, City Hall, Boston, Mass.	Jan. 13, 1892
Winslow, George E. Waltham, Mass.	June 18, 1885
Winslow, S. J. Superintendent Water Co., Pittsfield, N. H.	June 17, 1887
Wiswall, E. T. West Newton, Mass.	June 13, 1889
Wood, Henry B. Chief Engineer Topographical Survey, Room 138, State House, Boston, Mass.	Dec. 13, 1893
Woodruff, Timothy Supt. Water Works, Bridgeton, N. J.	June 13, 1888
Woods, Henry D. West Newton, Mass.	Jan. 9, 1895
Worthington, E., Jr. Civil Engineer, Dedham, Mass.	Jan. 11, 1893
Wright, George W. Chief Engineer Water Department, Box 426, Norfolk, Va.	June 9, 1892
Yorston, W. G. Constructing Engineer, Box 47 [illegible], Truro, N. S.	Dec. 14, 1892
Youngren, Carl J. Boston Water Dept., City Hall, Boston, Mass.	Dec. 13, 1899
Zick, W. G. 253 Broadway, New York City.	June 15, 1893

HONORARY MEMBERS.

NAME.	Date of Election.
Frost, George H. President Engineering News Pub. Co., St. Paul Building, New York City.	June 16, 1886
Gale, James M. Engineer-in-Chief Loch Katrine Water Works, Glasgow, Scotland.	Jan. 16, 1889
Meyer, Henry C. The Engineering Record, 100 William Street, New York City.	June 17, 1887
Shepperd, F. W. "Fire and Water," Bennett Bldg., Nassau and Fulton Streets, New York City.	Feb. 12, 1890

ASSOCIATES.

Allis, The Edward P. Co. "High Duty Pumping Engines," Milwaukee, Wis.	Dec. 13, 1893
Ashton Valve Co. "Water Relief Valves," 271 Franklin Street, Boston, Mass.	June 18, 1885
Barr Pumping Engine Co. Philadelphia, Pa.	Feb. 13, 1901
Betton, James M. Care H. R. Worthington, Box 14, Brooklyn, N. Y.	Dec. 12, 1888
Blake, The George F. Mfg. Co. "Pumping Engines," 54 Oliver Street, Boston, Mass.	June 21, 1883
Bond & Co., Harold L. 140 Pearl Street, Boston, Mass.	Dec. 12, 1900
Boston Lead Mfg. Co. 162 Congress Street, Boston, Mass.	April 21, 1885
Brandt, Randolph "Selden Patent Packing," 38 Cortlandt Street, New York City.	April 21, 1885
Brewster, H. M. (E. Stebbens Mfg. Co.) "Brass Goods," Brightwood P. O., Springfield, Mass.	June 13, 1888

NAME.	Date of Election
Builders' Iron Foundry P. O. Box 218, Providence.	June 17, 1887
Chadwick Lead Works 176 to 183 High Street. Boston, Mass.	April 21, 1885
Chapman Valve Mfg. Co. "Valves and Hydrants," Indian Orchard, Mass.	June 21, 1883
Claflin, Chas. A. Steam Engineering & Water Works Supplies, 188 Franklin Street, Boston, Mass.	Jan. 9, 1901
Coffin Valve Co. "Valves and Hydrants." Neponset, Boston, Mass.	June 16, 1886
Davidson, M. T. "Steam Pumps," 43 and 53 Keap Street, Brooklyn, N. Y.	June 19, 1882
Deane Steam Pump Co. "Steam Pumps and Pumping Machinery," Holyoke, Mass.	April 21, 1885
Dibble, F. J. "Electric Gauges," Peabody, Mass.	June 11, 1890
Drummond, M. J. "Cast Iron Pipe," 192 Broadway, Corbin Building, New York City.	Dec. 14, 1887
Dunne, George C. Manager Portland Stoneware Co., 42 Oliver Street, Boston, Mass.	Feb. 10, 1892
Eagle Oil & Supply Co. 104 Broad Street, Boston, Mass.	June 15, 1894
Fairbanks Co., The "Valves," 38 to 44 Pearl Street, Boston, Mass.	March 12, 1890
Garlock Packing Co., "Packing," 12 Pearl Street, Boston, Mass.	June 11, 1896
Gallison, William H. Co. "Engineer's Supplies, Pipe, etc.," 36 Oliver Street, Boston, Mass.	June 18, 1885
General Manufacturing Co. "Pumping Engines and Hydraulic Specialties," 275 Clinton Avenue, Brooklyn, N. Y.	June 15, 1894

NAME.	Date of Election.
Gilchrist, George E. "Pipes and Fittings," 106 High, corner Congress Street, Boston, Mass.	Jan. 11, 1888
Goulds Mfg. Co., The "Engines," 236 Congress Street, Boston, Mass.	Sept. 11, 1895
Helmer, W. K. Agent Holly Manufacturing Co., Lockport, N.Y.	Sept. 8, 1897
Hersey Manufacturing Co. "Meters," South Boston, Mass.	June 16, 1886
Holly Manufacturing Co. "Pumping Machinery," Lockport, N. Y.	June 10, 1891
Jenks, Henry F. "Drinking Fountains," Pawtucket, R. I.	April 21, 1885
Kennedy Valve Co. "Valves, Hydrants, and Indicating Devices," 57 Beekman and 87 Ann St., New York City.	Sept. 8, 1897
Lamb & Ritchie, Tin-lined Iron Pipe, and Lead-ined Iron Pipe, Cambridge, Mass.	Dec. 12, 1900
Lead Lined Iron Pipe Co. "Lead and Tin Lined Pipe," Wakefield, Mass.	Sept. 8, 1897
Libbey, Parker & Co. "Plumbing, Steam, Water Works Specialties and Supplies," 416 Atlantic Avenue, Boston, Mass.	March 14, 1900
Ludlow Valve Mfg. Co. "Valves and Hydrants," 150 High St., Boston, Mass.	June 18, 1885
Lynch, John E. Proprietor "E. Hodge & Co., Stand Pipes," East Boston, Mass.	June 10, 1891
Michigan Brass and Iron Works. "Valves, Hydrants, and Brass Goods," Detroit, Mich.	June 13, 1889
Moore, Charles A. "Engines, Boilers, and Supplies," 85 Liberty Street, New York City.	Dec. 9, 1896
Morris, I. P. Co. "Pumping Engines and Turbines," cor. Beach and Ball Streets, Philadelphia, Pa.	June 15, 1894

NAME.	Date of Election.
Mueller, H. Mfg. Co. "Water Works Supplies," Decatur, Ill.	Sept. 11, 1895
National Lead Co. (Boston Branch) 89 State Street, Boston, Mass.	March 14, 1894
National Meter Co. "Meters," 84 Chambers Street, New York City.	Oct. 11, 1882
National Tube Co. "Pipe and Fittings," McKeesport, Penn. Address 95 Milk Street, Boston, Mass.	April 21, 1885
Neptune Meter Co. "Trident Water Meters," Jackson Avenue and Crane Street, Long Island City, New York.	June 15, 1893
New York Filter Mfg. Co. "Filters," 15 Broad St., New York City.	June 15, 1894
Norwood Engineering Co. "Hydrants, Filters, etc.," Florence, Mass.	April 21, 1885
Peck Bros. & Co. "Water Works Supplies," 65 Oliver Street, Boston, Mass.	Dec. 12, 1894
Perrin, Seamans & Co. "Construction Tools and Supplies," 57 Oliver Street, Boston, Mass.	June 11, 1890
Pittsburg Meter Co. "Water Meters," East Pittsburg, Penn.	June 15, 1894
Rensselaer Mfg. Co. "Valves and Water Gates, and sole Mfgrs. of Corey Fire Hydrant," Troy, N. Y.	June 11, 1890
Roberts, C. E. Hartford Steam Boiler Inspection and Insurance Company, 125 Milk Street, Telephone Building, Boston, Mass.	March 13, 1889
Robinson, Edward "Wells Light Mfg. Co.," 44-46 Washington St., New York City.	Dec. 13, 1899
Ross Valve Co. "Valves," Troy, N. Y.	June 13, 1888
Sampson, George H. "Powder," 13 Pearl Street, Boston, Mass.	June 18, 1885

NAME.	Date of Election.
Smith, A. P. Mfg. Co. "Tapping Machines," Passaic Avenue, foot of Brill Street, Newark, N. J.	Feb. 10, 1892
Smith, Benjamin C. "Water Works Supplies," 275 Pearl Street, New York City.	June 15, 1893
Smith, B. F. & Bro. "Artesian and Driven Wells," 38 Oliver Street, Boston, Mass.	Sept. 10, 1897
Snow, Franklin A. Civil Engineer and Contractor, 490 Broad St., Providence, R. I.	Jan. 10, 1894
Snow Steam Pump Works, The "Steam Pumps," Buffalo, N. Y.	Dec. 12, 1894
Sumner & Goodwin Co. "Water Works Supplies," 287 Congress Street, Boston, Mass.	April 21, 1885
Sweet & Doyle, Selling Agents "Vincent Valves," Cohoes, N. Y.	June 13, 1900
Thomson Meter Co. "Water Meters," 79 Washington Street, Brooklyn, N. Y.	June 13, 1888
Union Water Meter Co. "Water Meters," 31 Hermon Street, Worcester, Mass.	June 21, 1883
United States Cast Iron Pipe & Foundry Co. Cor. Broad and Chestnut Sts., Philadelphia, Pa.	Sept. 13, 1899
Waldo Bros. "Contractors' Supplies," 102 Milk Street, Boston, Mass.	April 21, 1885
Walworth Mfg. Co. "Pipe, Brass Work, Service Boxes, etc.," 134 Federal Street, Boston, Mass.	April 21, 1885
Wilfendale, William Agent for Plumbers' Supplies, 76 Second Street, Fall River, Mass.	June 13, 1889

NAME.	Date of Election.
Wood, R. D. & Co. "Cast Iron Pipe," 400 Chestnut Street, Philadelphia, Penn.	June 19, 1884
Woodman Co., The George "Pipe and Fittings," 41 Pearl Street, Boston, Mass. P. O. Box 3653.	April 21, 1885
Worthington, H. R. "Pumping Engines," Hydraulic Works, South Brooklyn, N. Y.	June 19, 1884